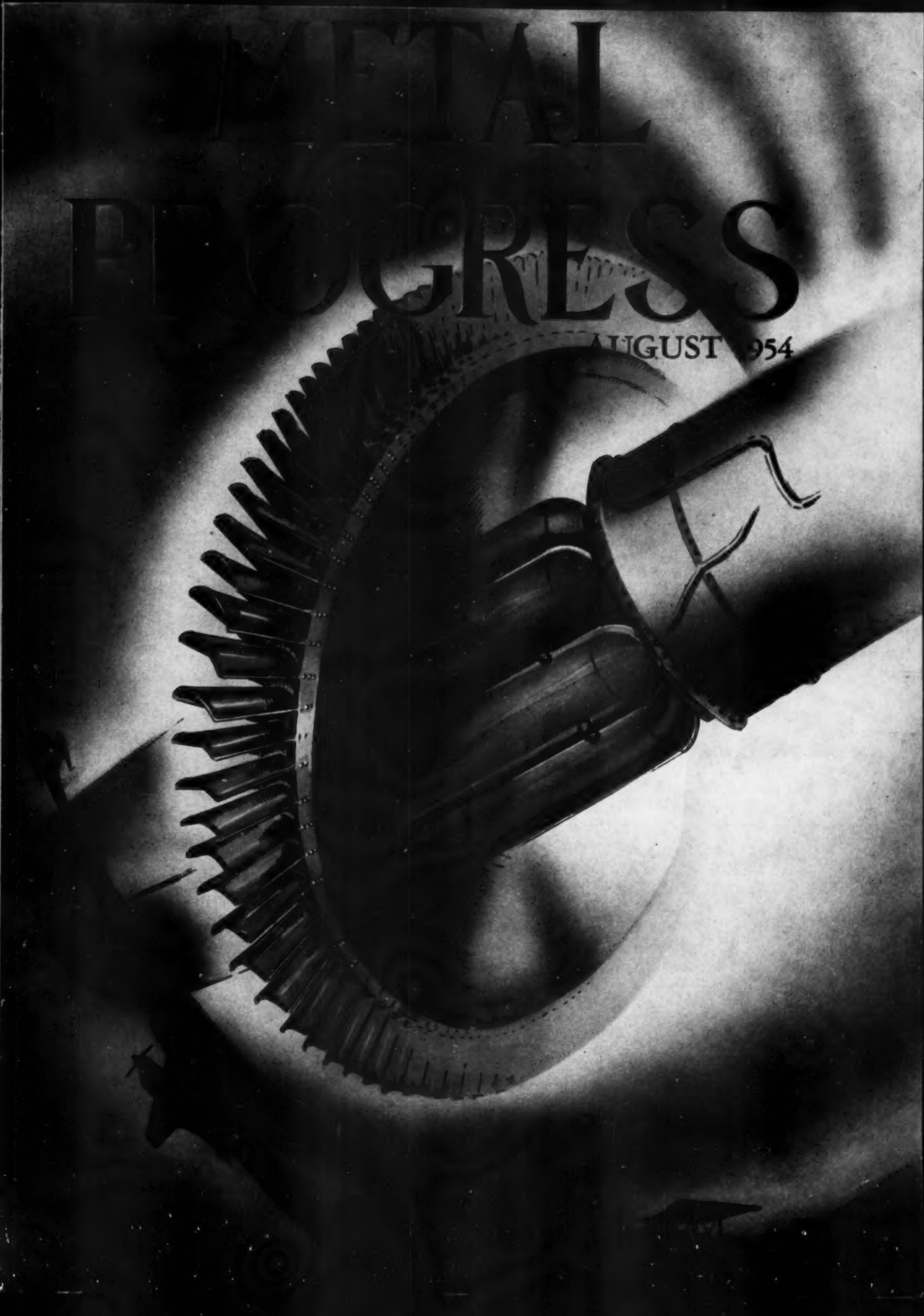
METAL PROGRESS

AUGUST 1954



Metal Progress

August, 1954 **Vol. 66, No. 2**

Cover by John Wozny

Engineering Articles

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Send for this new bulletin on

THERMALLOY* FURNACE CONVEYOR BELTS

See how design know-how and modern foundry practices can produce high alloy conveyor belts that last longer in heat treating operations

In this new bulletin you will see how Electro-Alloys engineers started with certain design theories about high temperature conveyor belts . . . and how these ideas directed the production of heat-resistant Thermalloy castings. You will see the importance attached to precision assembly of these castings into Thermalloy Conveyor Belts.

Finally, you will be interested to know that Electro-Alloys has established unique testing procedures that will give you a good indication of what can be expected from Thermalloy Conveyor Belts in operation. These results are shown in a composite load curve chart in the bulletin. And, Electro-Alloys engineers can apply these results to your installation... so you can get longer service life from Thermalloy Conveyor Belts in your heat treating furnaces.

Start planning now to use Thermalloy Conveyor Belts to lower operating costs. Write for your free copy of Bulletin T-241 . . . Electro-Alloys Division, 5002 Taylor Street, Elyria, Ohio.

AMERICAN Brake Shoe COMPANY

ELECTRO-ALLOYS DIVISION
Elyria, Ohio

*Reg. U. S. Pat. Off.

Table of Contents Continued

As I was saying...

It's always nice to see ASM members given a pat on the back and so I get a particular thrill from the comments of Les Gillette in the *Metal Progress* ad in this issue on pages 174 and 175.

As you know, Les is manager of industrial heating sales at Westinghouse and he remarks that their furnaces and generators are produced under complete metals engineering control—from design and development to selection of all materials and components required—*and* these metals engineers are all members of ASM. That's a splendid endorsement of the well-known importance and influence of ASM'ers!

Incidentally, Les is president of the Industrial Furnace Manufacturers' Association this year and this important group will present an outstanding series of panel sessions as a part of ASM's overall program at the Chicago Metal Show. Cary Stevenson of Lindberg is in charge of this panel activity as chairman of IFMA's public relations committee.

There will be three sessions, two on atmosphere control and the third on induction heating. They will be held Tuesday and Wednesday during the Show. I'll bet the SRO sign will greet the late comers to those meetings.

The ASM Publications Committee was in headquarters last week and selected 40 top-rated technical papers for presentation at the Chicago meeting, November 1 to 5. All sessions will be held at the Palmer House but the educational lecture series will be at the Saddle & Sirloin Club adjoining the Metal Show.

By this time you will have had an opportunity to thumb through the Metals Handbook Supplement and get some appreciation of the outstanding job the Committees did in preparing the material. It's another example of the willingness of the ASM member to take off his coat and dig in whenever there is an educational job to be done.—Many thanks.

The announcement of a new relatively low-cost atomic reactor to be used in training technicians for the nuclear power industry as well as providing facilities for conducting basic nuclear research and development reminded me again that this Atomic Age is really the Metallurgist's Age. It's sure right up the metallurgist's alley and the metals engineer (the ASMer) is the important cog in this gigantic project. Only the other day the personnel man of a company operating three large nuclear laboratories was in asking help to locate more men.

All of us have always realized the important part the metals engineer plays in all successful plant operations but for some unknown reason his importance and value are not always recognized—but Mr. Atom's dependence on the metallurgist has placed this engineer right at the tiptop of a new great far-reaching industry—and we're mighty happy for both the industry and The Man.

I've just mailed the second information letter to those who have registered to indicate their interest in securing latest details of the ASM trip to Europe in '55 to attend the Joint Metallurgical Societies Meetings, June 1 to 20th in London, Dusseldorf and Paris. Why not send in your name? Need I remind you—"You can't take it with you!"

Hope your family and you are having a fine pleasant summer and that the Missus is planning to bring you to the National Metal Congress and Exposition in Chicago, November 1 through 5.

Cordially Yours,

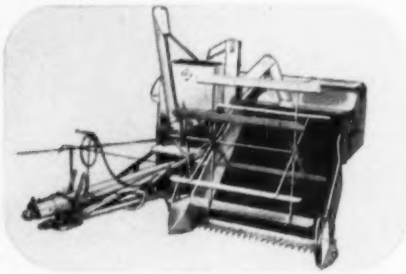
Bill

W. H. Eisenman, *Secretary*
American Society for Metals

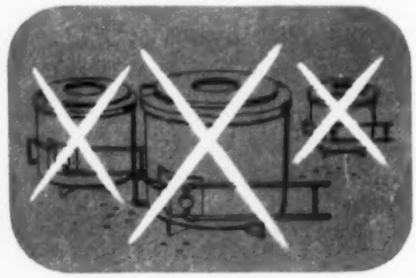
"Cyanide pots scratched . . . LINDBERG Carbonitriding Furnaces win in a walk!"

1. Owner, Allis-Chalmers, internationally known maker of farm machinery.

2. Allis-Chalmers purchased 3 Lindberg Carbonitriding Furnaces for its La Porte Works.

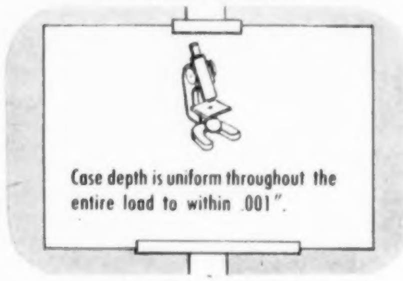


3. Furnaces used to heat-treat farm machinery parts—from a few ounces to 5 pounds.

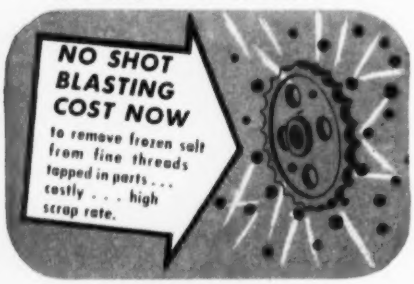


4. Old salt pots did not provide needed volume or desired uniformity of case depth.

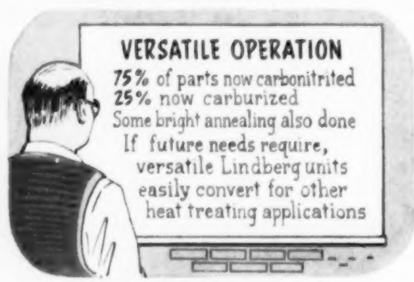
5. This factor represents a tangible, specific saving in operating and labor costs.



6. In addition to this advantage, working conditions were substantially improved.



7. Shot blasting eliminated... case depth requirements of .005 to .030 met.



8. Neutral hardening, carbon correction, tool treating—done with simple switch-over.

HOW ABOUT YOUR PLANT?

Perhaps we can help solve a production problem that will increase output, improve working conditions, and cut costs in your plant, too.

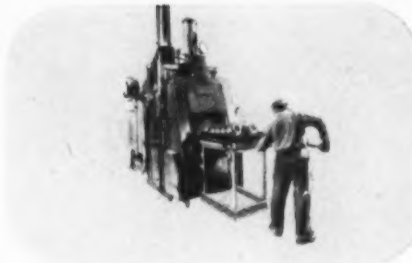
Write for our Bulletin No. 241.

LINDBERG FURNACES

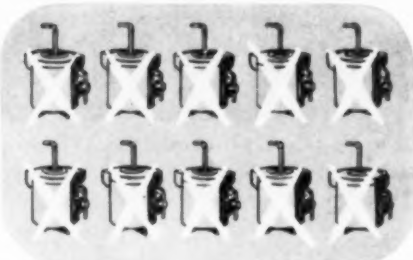
LINDBERG ENGINEERING COMPANY
2448 W. Hubbard Street • Chicago 12, Illinois

"10 little cyanide pots ..and then there were none"

1. Featuring Singer Sewing Machines and Lindberg Carbo-nitriding Furnaces.



2. Singer Manufacturing Co. bought a new Lindberg Carbo-nitriding furnace.

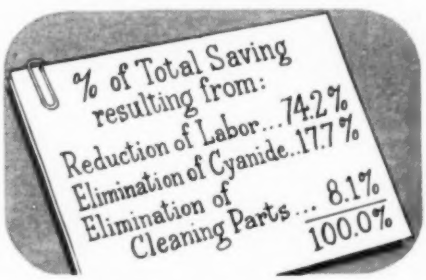


3. It replaced 10 liquid cyanide furnaces.

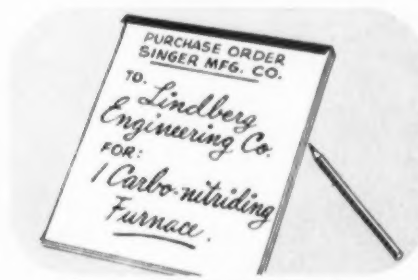
4. The new furnace heat treats parts for "industrial sewing machines" . . . used for stitching canvas, mattresses, overalls, etc.

5. In 12 months, the new Lindberg Carbo-nitriding furnace paid for itself in savings.

6. Mr. Lloyd R. Raymond, Supt. of heat treating at Bridgeport plant of Singer.



7. . . . submitted this report to his top management.



8. . . . with this requisition for a second Lindberg Carbo-nitriding furnace (to double production of carbonitrided parts).

End of Story

LINDBERG FURNACES

LINDBERG ENGINEERING COMPANY

2448 W. Hubbard Street • Chicago 12, Illinois

→→→→→→→→

than REMOVING it!

. . . Stainless steel is successfully hot extruded in a wide variety of shapes with cross-sectional areas ranging from 0.5 to 3.0 sq. ins. and in lengths of 12 to 60 ft.

. . . Titanium, zirconium, tool steel and high temperature alloys are being extruded experimentally with good results.

• The big trend in metalworking today is to force metal into a desired shape rather than to shape it by machining. This results in new and better products at lower cost. In addition to the type of extrusion done by the Allegheny Ludlum Steel Corporation, these new processes include cold "pressure" forging of aluminum, cold extrusion of steel, and high pressure closed die extruding of aluminum, brass and other non-ferrous alloys. Also falling within this category are somewhat older though greatly changed and improved methods for the extrusion of aluminum, hot forging of ferrous metals, powder metallurgy, deep drawing of sheet and die casting. These new and improved production techniques are already saving millions of dollars in materials and production time. Lake Erie engineers are in the forefront of these developments. They will be glad to explore applications in your production. No obligation. Call us.

• Typical sections hot extruded by Allegheny Ludlum from series 300 and 400 grades of stainless steel. Included in current production are jet engine rings, turbine blades, special shapes for electronic equipment and similar products. Pieces generally have equal or improved physicals including density and grain structure when produced by "moving the metal rather than removing it."

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HYDRAULIC
PRESSES

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District Offices in New York, Chicago, Detroit, Pittsburgh

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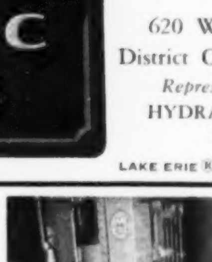
HYDRAULIC PRESSES • DIE CASTING MACHINES
ROLLING MILL AUXILIARY EQUIPMENT

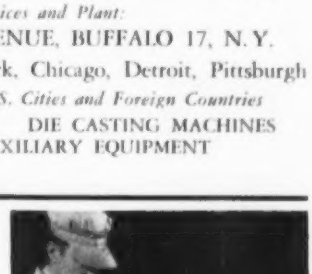
LAKE ERIE ®

Closed die extruding of heated aluminum is reducing production time 99% for one Lake Erie customer. ←

Cold steel extrusion is reducing scrap 43% and practically eliminating machining for another Lake Erie customer. →



Stainless, seamless tubing is another major product of the Allegheny Ludlum Extrusion Plant. →



Whatever your furnace needs for control—

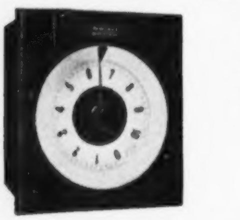
There's good reason why more heat-treating furnaces everywhere are controlled by Brown instruments. First, of course, is performance . . . sensitive, precise control that meets the most exacting requirements of modern heat-treating techniques. And equally important is versatility. In this varied line of instrumentation you'll find just about everything a furnace could possibly need in the way of control.

Just check through the requirements of your specific heat-treating problem . . . then look through this group of instruments and accessories:

Choose *ElectroniK* Strip Chart Controllers for detailed, long-term records . . . and a selection of control forms including electric systems of the contact, position-proportioning (*Electr-O-Line*) and time-proportioning (*Electr-O-Pulse*) types; and pneumatic control from two-position to full proportional-plus-reset-plus-rate action.

Choose *ElectroniK* Circular Chart Controllers for ease of scale reading . . . convenient daily charts; in a full range of electric and pneumatic control forms.

Choose *ElectroniK* Circular Scale Controllers where you want readability and control check at extreme distance . . . without need for a record. Supplied with all contact and proportional types of electric control.



Choose *Pyr-O-Vane* Controllers where you don't need a record but do need precise vane type snap action electric control by a millivoltmeter instrument.

Choose *Protect-O-Vane* Controllers for simple, dependable excess temperature cut-off protection.

• • •

And for all your pyrometer supplies, investigate the HSM Plan—the convenient way to buy the best in supplies on a schedule custom-fitted to your plant . . . at advantageous discount schedules.

Flexibility for parts carburizing at Caterpillar®— in *ElectroniK*-

Detailed information on all Brown instruments for regulating heat-treating equipment is contained in Catalog 54-1, "Furnace and Oven Controls" . . . complete with up-to-date prices. Write for your copy today . . . or get one from your local Honeywell sales engineer next time he calls.

Track link bushings for Caterpillar Crawler Tractors . . . famous for 50 years . . . are carburized in these Surface Combustion furnaces, under precise time-temperature control by **ElectroniK** *instruments on the panels in the background.*

controlled Surface pit furnaces

HIGH QUALITY carburizing at high production rates — this is the goal that is achieved at Caterpillar Tractor Co. Eighteen pit-type Surface Combustion furnaces carburize more than 400 tons of track link bushings every week, to strict specifications that insure long service life.

The control system for each furnace is engineered to give both the precision and the high degree of control essential to volume production. The system with *ElectroniK* Controllers regulates fuel input to the radiant-tube burners and conducts the furnaces through preset time-temperature programs. Purge, equalizing, carburizing, diffusion and cooling periods are automatically followed . . . and are readily changed when required to meet various carburizing specifications. At each change point in the cycle, signal lights inform the operator of the progress of the furnace charge.

As a safety measure, each furnace is equipped with a *Protect-O-Vane* millivoltmeter controller, which will instantly shut off fuel flow in the event of excess temperature.

The wide line of Honeywell instrumentation includes controlling, recording and protective equipment applicable to literally any kind of heat-treating furnace. For a discussion of your individual requirements, call your nearby Honeywell sales engineer . . . he's as near as your phone.

MINNEAPOLIS-HONEYWELL REGULATOR CO., *Industrial Division*, Wayne and Windrim Avenues, Philadelphia 44, Pa.

● **REFERENCE DATA:** Write for Catalog 1531, "*ElectroniK* Controllers," and for Catalog 54-1, "Furnace and Oven Controls."

H HONEYWELL

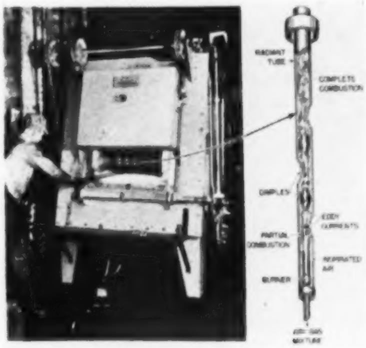
MINNEAPOLIS
Honeywell
BROWN INSTRUMENTS

First in Controls

engineering digest OF NEW PRODUCTS

Radiant Tube Furnace

Lindberg Engineering Co. has announced a new gas-fired radiant tube atmosphere furnace. In the new furnace the center stream is a mixture of gas and a relatively small amount of air, insufficient for complete com-



bustion. Indentations are placed around the circumference of the tube, top to bottom, to set up eddy currents which mix air with some of the air-gas mixture, accelerating the combustion rate. As the streams move further upward, additional "dimples" continue the mixing until completed. The thin-walled Inconel tubes are suspended along the sides of the furnace chamber, and are readily removable without cooling the furnace. Maximum operating temperature is 1850° F.

For further information circle No. 653 on literature request card on p. 32-B.

Aluminum Coated Wire

An aluminum coated steel wire has been announced by the Page Steel and Wire Div., American Chain & Cable Co. Application of the aluminum coating is made through a new continuous hot-dip process, with close control of thickness and weight of coating. The coating is bonded tightly to its metal base and is so ductile that it can be drawn to any desired thickness. Based on coatings of equal thickness to that of zinc, resistance to weathering in industrial atmospheres is expected to be 2 to 20 times as long. It is available in aluminized 7-wire strand in openhearth high strength and utility grades of steel. Physical properties conform to ASTM Specification A122-52-T for galvanized strand.

For further information circle No. 654 on literature request card on p. 32-B.

Dry Film Coatings

Acheson Colloids Co. has announced the availability of two new dispersions, No. 213, containing colloidal graphite, and No. 223, containing colloidal molybdenum disulphide. These two products offer the advantages of the new epoxy resins as a base for dry, lubricating coatings. Films formed are unaffected by oils and solvents, and can be used whereever temperatures do not go above 500° F. All types of surfaces can be coated. The two dispersions can be mixed to produce films containing both colloidal graphite and molybdenum disulfide. Both dispersions should be treated alike, so far as dilution and methods of application are concerned.

For further information circle No. 655 on literature request card on p. 32-B.

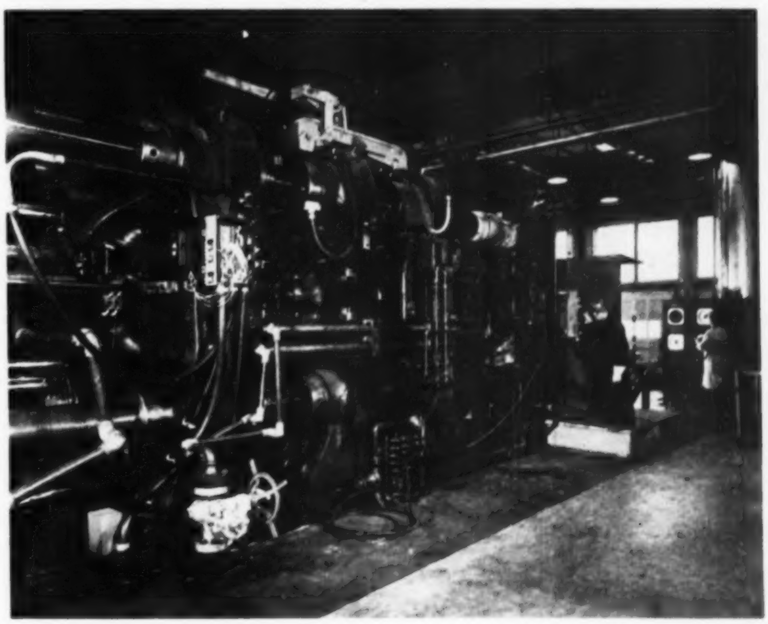
Cleaning Barrels

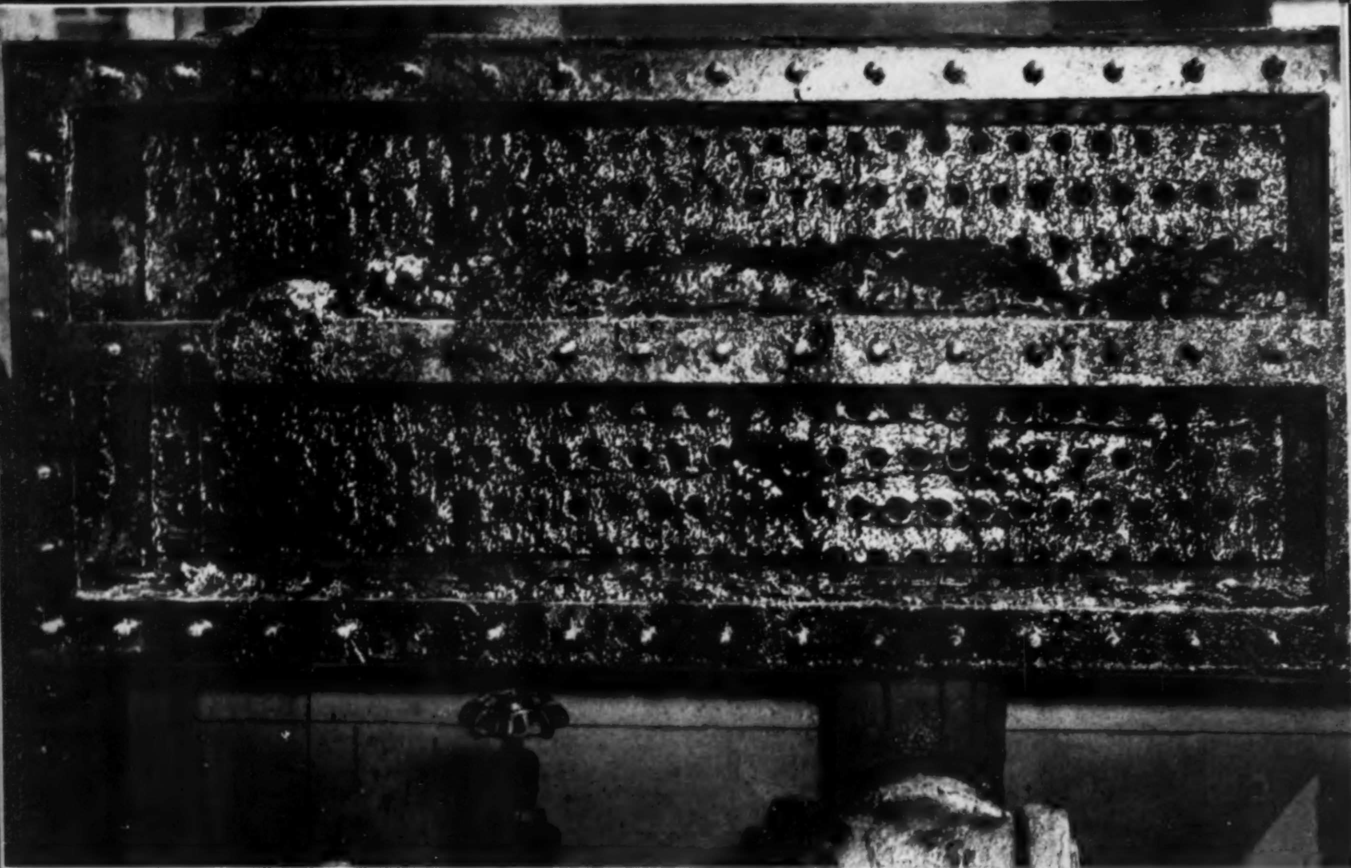
Pangborn Corp. has announced the availability of five sizes of Type GO continuous-flow rotoblast cleaning barrels ranging from a 48 to 72 in. diameter drum. These barrels are best suited for integration with automatic operations, so that conveyors can bring castings or forgings directly into the barrel, where they are continuously moved through while being tumbled and blast cleaned. All

Aluminum Die Castings

Aluminum die castings weighing up to 75 lb. are now possible according to an announcement by Doehler-Jarvis Div. The 72-in. machine producing these is a mechanical unit weighing 250 tons which can handle dies to 50 tons. It is estimated that 300 of these 75-lb aluminum castings can be made in an hour, consuming 2250 lb. of metal. To cope with the high rate of metal consumption the machine is equipped with two 12,000-lb. reverberatory furnaces. When the unit is adapted to zinc use, it is contemplated that parts up to 200 lb. can be cast.

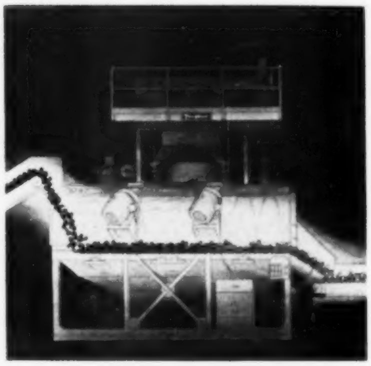
For further information circle No. 656 on literature request card on p. 32-B.





If you use an ordinary quenching oil that forms sludge deposits, here's what can happen to your oil cooler.

abrasive is reclaimed before cleaned parts are discharged from the barrel. The abrasive separation system thoroughly cleans the abrasive for re-use. These barrels are rated by the



amount of work they can clean in an hour, the No. 5, 72-in. barrel cleaning 300 to 400 cu. ft. of gray iron castings or 150 to 250 cu. ft. of forgings up to 26-in. maximum dimension in 1 hr.
For further information circle No. 657 on literature request card on p. 32-B.

Impact Tester

Tinius Olsen has announced a new automatic progressive and repeat impact testing machine for determining the breaking point of gear teeth and studying the dynamic properties of parts subject to shock. In operation, a hammer of known weight is automatically raised and dropped on the test specimen from progressively higher points until the specimen breaks. The quality of the material under test can be determined from the height of the fall at fracture and number of blows delivered. Height of fall is increased by one inch increments for each succeeding stroke. The machine can also be set to deliver the impact repeatedly from any desired height between 6 in. and 10 ft.

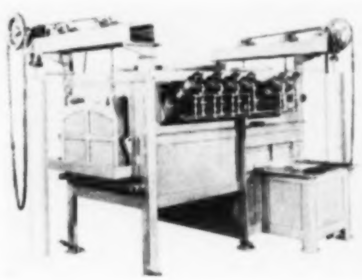
For further information circle No. 658 on literature request card on p. 32-B.

High-Temperature Tubing

An alloy steel seamless tube, for use in equipment operating under conditions of high stress and temperature, has been announced by the Tubular Products Div. of Babcock & Wilcox Co. It is produced by the hot extrusion process in a limited size range in seamless tubing. The steel, 19-9DL, is a predominately austenitic stainless steel containing chromium, nickel, molybdenum, tungsten and small quantities of columbium, tantalum and titanium. At present, it is most commonly used in jet engines, experimental aircraft and gas turbines.
For further information circle No. 659 on literature request card on p. 32-B.

Aluminum Melting

A new dry hearth double-chamber furnace for melting, die casting, or permanent molding of aluminum has been announced by Eclipse Fuel Engineering Co. Melting and holding baths are included in a single unit.



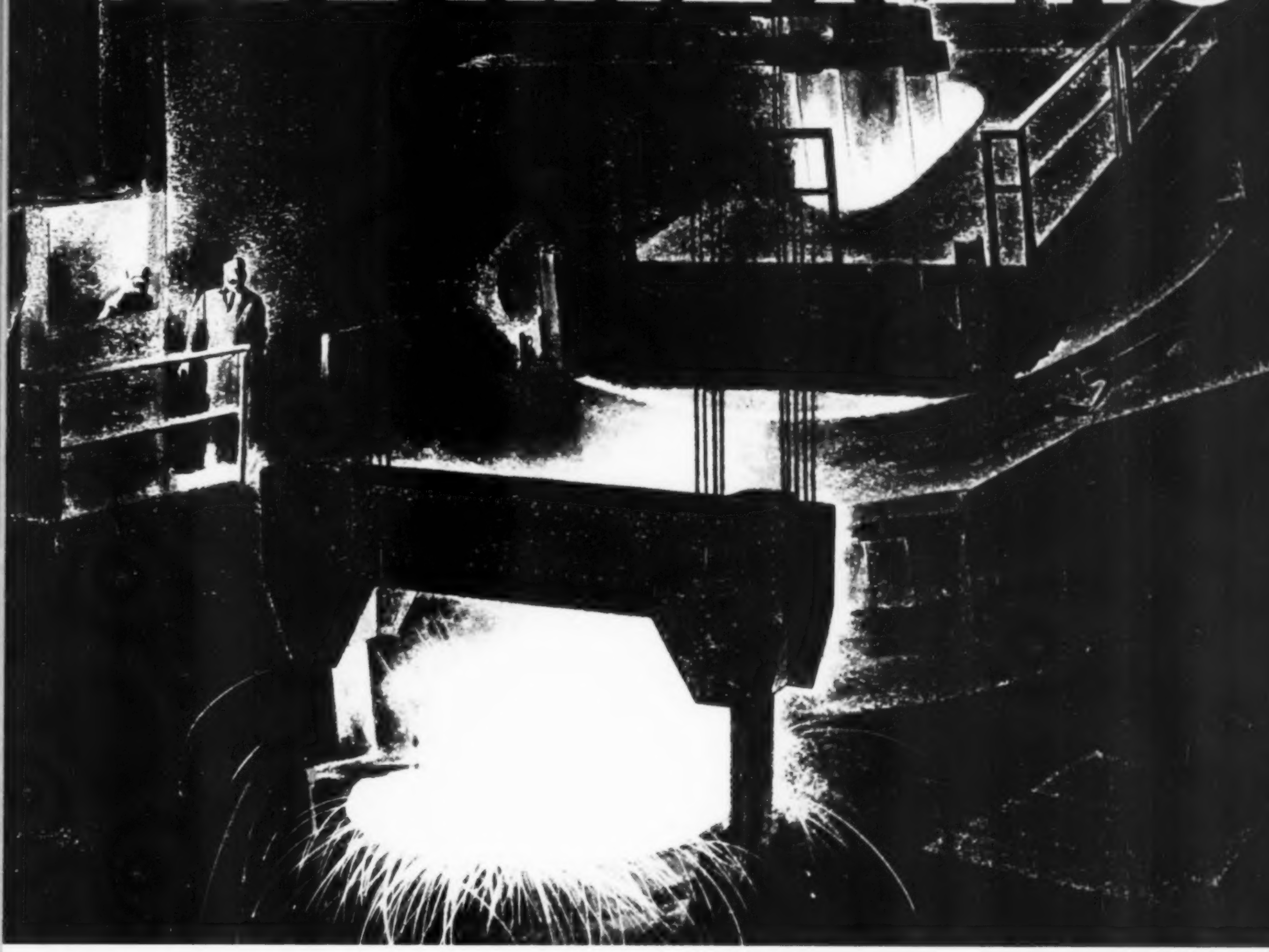
Aluminum is charged through the door into the sloping hearth which allows the molten aluminum to flow into the holding compartment, where uniform temperature is maintained. Two dip vestibules are provided. Design eliminates gassing of metal, making the furnace suitable for production of precision die cast parts and permanent mold castings. Furnaces are available in 12 standard sizes up to 2000 lb. per hour capacity, for gas, oil or combination gas-oil firing.
For further information circle No. 660 on literature request card on p. 32-B.

Electrode Holder

A molded glass fiber handle is one of the key features of the newly announced 14 oz., 300 amp. Caddy Cub electrode holder, manufactured by Erico Products, Inc. The use of glass fiber in the handle provides a handle with high tensile strength that is also

NATIONAL CARBON COMPANY'S

CARBON AND GRAPHITE NEWS



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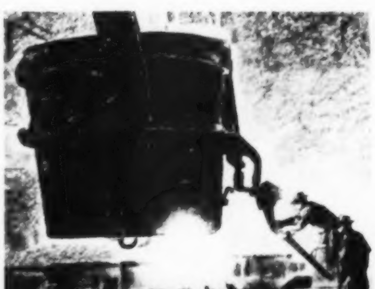


"........ Open-hearths may be hard to find," is the interesting observation by our Guest Editor. See the feature article by............

William B. Wallis, Past President of the American Foundrymen's Society and currently President of the Foundry Equipment Manufacturers Association.

"...... a myriad of new and useful products in the creative inferno of the electric arc." A review of other arc-furnace applications.

CARBON AND GRAPHITE NEWS · August, 1954 · Vol. 1, No. 1

WE COMPLIMENT the steelmakers of America for their daring and farsightedness. They have brought about a dynamic and steady growth in steel, our most important and vital American industry.

As the oldest and largest supplier of carbon and graphite products, National Carbon Company has contributed to this great industry by continual product improvement through ever-expanding research and development. Our Company is proud of this contribution but also is fully aware of its responsibilities to continue to serve steelmakers. We must not only produce even better products for you, but we must tell you about them and about other developments in the fields where these products are used.

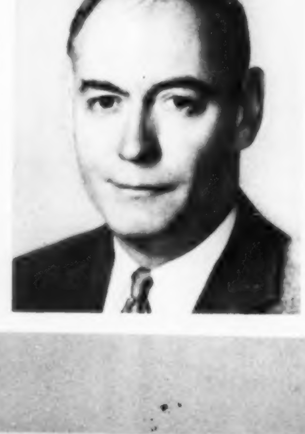
To this end, a regular series of reports, of which this is the first, is being sponsored by our Company, covering significant developments in steel-mill and foundry practice involving the electric furnace.

To bring you the most complete, up-to-date information, we plan to make a major share of these editorial pages available to recognized authorities outside our own organization . . . men who, as consultants, design engineers, metallurgists, furnace operators and manufacturers, have distinguished themselves in their respective fields.

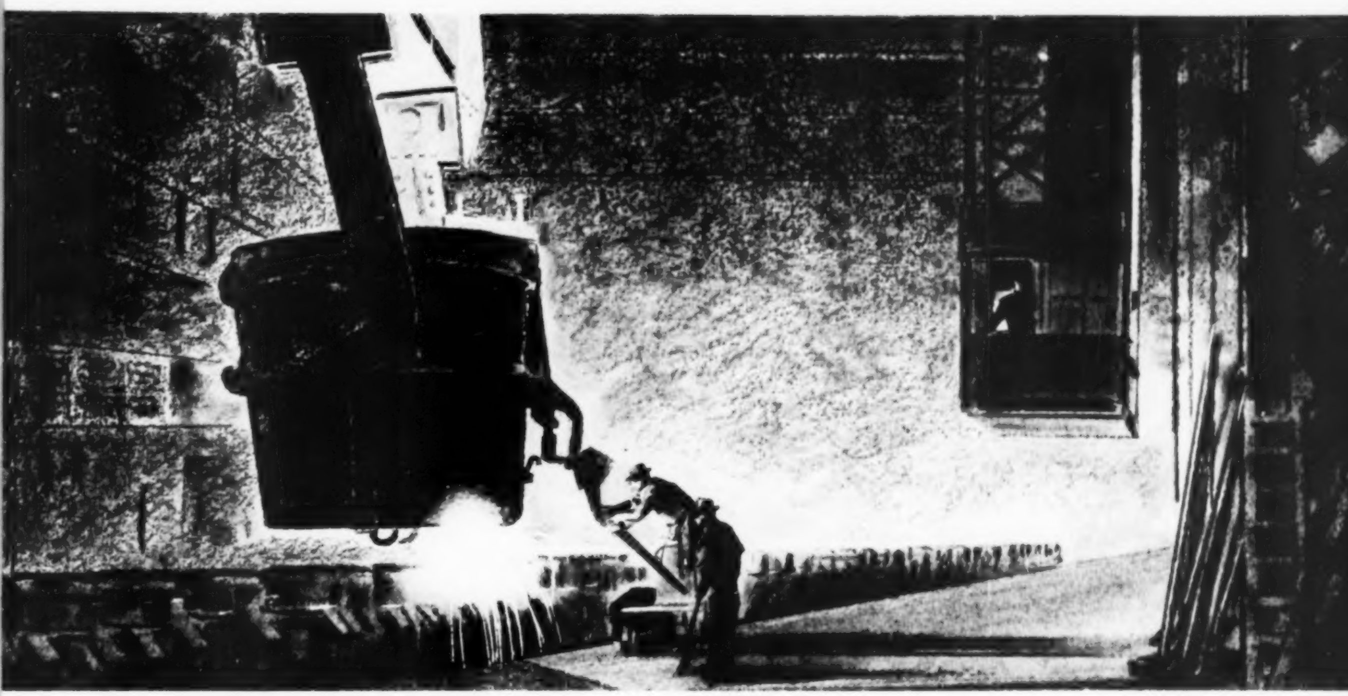
The vital business of making iron and steel — better and more economically — remains a constant challenge. Subsequent issues will present information on ways in which this challenge is being met.

A Johnson

PRESIDENT



NATIONAL CARBON COMPANY
A Division of Union Carbide and Carbon Corporation
30 East 42nd Street, New York 17, New York
In Canada: Union Carbide Canada Limited, Toronto



ELECTRIC FURNACE STEEL—
PAST, PRESENT AND FUTURE... *by W. B. Wallis*

IT HAS been my good fortune to watch the development of the electric arc furnace in both the ingot and casting fields over a number of years. At no time in the past forty years of active participation in the industry has the picture been as bright as it is today.

With this healthy and encouraging prospect in view, it seems appropriate to inquire into the reasons why this now-widely accepted instrument of steel production was so long in coming of age in a country famous for the speed of its technological progress.

EARLY FACTORS RETARDING GROWTH

The electric arc furnace entered the American steel industry during the period between 1906 and 1920, when the country was producing a relatively large quantity of steel each year and was annually increasing that quantity at a rapidly-accelerating rate. Furthermore, the electric furnace was not christened as a common-steel producer, but rather as a specialized tool for the making of special steels to replace products of the crucible.

In its approach to the common-quality steel picture, the electric furnace was compelled, thirty-two years ago, to go into the small, independent mills. From that early beginning it developed very slowly to the making of billet-size ingots for reinforcing rods – a type of ingot production that was of no interest to the tonnage producer. Electric-furnace installations were made in Texas, Alabama, Washington, Indiana, Tennessee, Ohio and Pennsylvania as a result of the Canadian success in producing the first billet-size ingots. Canada also was first to install thirty-ton electrics for the production of common-quality steels. It is important to point out that it was this background of *gradually* accelerating electric-furnace production of common steels in the smaller mills that slowly brought the arc furnace to the attention of the big ingot producers.

RECENT FACTORS ENCOURAGING GROWTH

Electric-furnace steel production experienced a meteoric increase of 60 per cent during the four-year period between 1949 and 1953. Responsible and informed analysts of our steel economy have attributed this rapid growth to the availability of top-charging furnace designs and high-powered substations.

Their theory does not check completely with the record nor explain all the facts.

Figure I sets up the progress of top-charge, high-powered furnace installations in the U. S. A. Clearly, the 1949-53 growth did not wait upon modern furnace design or adequate power facilities – these had been available for twenty-two years. Nor can we reasonably suppose that this accumulation of experience with top-charging practice suddenly, and for no other, more basic reason, flowered into unprecedented acceptance.

Rather, to adequately understand and explain this sudden increase in electric-furnace capacity, we must look at the record of *common*-steel production in this country since 1910 – a record which may help to explain why electric-furnace growth was so long in coming.

In Figure II, the per cent of increase in total steel production is related to corresponding percentage increases in electric-furnace production for the periods 1910-20, 1920-40, 1940-49 and 1949-53. Right up to 1949, we find a fast-growing overall-production pattern, paralleled by relatively sluggish growth in electric-furnace capacity. Tonnage figures shown for each period indicate the huge *mass* involved in the industry's increasing *velocity* of growth – MV^2, if you will, always far ahead of any other in the world.

The first significant break in our steel industry's constantly accelerating MV^2 came in 1949. Then, for the first time, American steel producers had *time* to evaluate electric-furnace economics in the light of:

PROGRESS OF TOP-CHARGE ELECTRIC FURNACE INSTALLATIONS IN THE U. S. A.

Year	Size of Furnace	Size of Substation	Kw/ft.2 Hearth Area	Tonnage Per Heat
1927	11 ft.	5000 KVA	100	12 tons
1929	12 ft.	5000 KVA	78	20 tons
1938	15 ft.	12500 KVA	110	30 tons
1940	17 ft.	15000 KVA	98	50 tons
1948	18 ft.	16000 KVA	90	70 tons
1949	19 ft.	18000 KVA	90	85 tons
1950	20 ft.	25000 KVA	110	95 tons
1951	22 ft.	36000 KVA	127	135 tons
1954	24 ft.	36000 KVA	104	150 tons
1954	24'-6"	25000 KVA	69	175 tons

FIGURE I

1. Large-capacity, high-powered, top-charge furnaces.
2. Almost a generation of experience with this accepted, modern type of design.
3. Most importantly, an industry whose tremendous mass-acceleration had reached, for the first time in 43 years, a condition of equilibrium.

At least one observation is quite obvious: that expansion of the electric furnace since its beginning in the United States has been inversely proportional to the mass-acceleration of the steel industry as a whole. If this fact suggests, as it does to the writer, a theory valid in the explanation of our own electric-furnace history — its long, slow growth and sudden expansion — the same theory should be equally valid when applied to electric-furnace development abroad. Such definitely is the case, as shown in Figure III. Here again, electric-furnace steel production experienced its greatest growth during the period when the European steel maker had *time* to study the electric furnace as applied to his economics. For example, prior to World War II, France and England had pushed their production of electric-furnace steel to about 11 per cent and Germany to about 7 per cent. Sweden and Italy, where tonnage factors were lower prior to World War II, each produced about 27 per cent of the national output by the electric-furnace process. Even in the one period (1920-40) during which the per cent increase, or *velocity*, of production elsewhere in the world exceeded our own, the total *mass* involved abroad never approached that established early in this country's history.

EFFICIENCY OF ELECTRIC FURNACE vs. OPEN-HEARTH

A most interesting report was made in 1953 by the Bituminous Coal Research, Incorporated[1]. In this well-known report the Battelle Memorial Institute takes a look at the open-hearth furnace, long the standard ingot producer in this country, and points out that only about 25 per cent of the heat introduced in the open-hearth is delivered in the steel poured; whereas in the electric furnace, 75 per cent of the heat introduced is in the steel poured, all of which means that future study of the open-hearth must consider more carefully this matter of overall heat-balance in an attempt to improve its efficiency.

On the opposite page, Figures IV and V are tables of heat balance as published on pages 31 and 32 of the Battelle Memorial Institute report.

ECONOMICS WITH COLD-SCRAP CHARGE

Steel production in this country is grouped into two types of plants: (1) 100 per cent cold-scrap plant; (2) the integrated plant. As the result of experience over the past nineteen years with high-powered, top-charge furnaces making common-quality steel, the ingot industry has accepted the fact that the electric furnace can produce common-quality steel ingots for less money than the open-hearth, where 100 per cent cold-scrap charges are used.

There recently have been two notable papers by members of the industry that emphasize the foregoing — that of Leo Reinartz[2], December 1953, before the American Iron and Steel Institute of Philadelphia, and the Howe Memorial Lecture by C. D. King[3], Feb. 16, 1954, before the A.I.M.E.

The electric furnace not only can produce ingots for less money with 100 per cent cold scrap, but, size for size, it can produce double the tonnage of the open-hearth on the same quality steel. As has been repeatedly pointed out, where cold-scrap charges are considered, the cost of electric-furnace plant buildings, cranes, ladles, etc., represents about 60 per cent of the investment required for an equivalent-capacity, open-hearth shop.

Furthermore, the electric furnace has considerable advantage over the open-hearth in the overall yield of ingots produced from scrap charged. Again, it has a higher availability than the open-hearth for the reason that the down times for relining are relatively short.

Figure VI gives hourly production rates on top-charged, higher-powered electric furnaces during the year 1953.

INTEGRATED PLANTS

Steel producers have accepted the fact that in cold-melt shops employing 100 per cent scrap, the electric furnace is a cheaper producer of ingots than the open-hearth. Some, however, are approaching consideration of the electric furnace as applied to integrated plants with a good deal of hesitation. There are three approaches to the use of the arc furnace in integrated plants: (1) Duplicating open-hearth practice; (2) duplexing blown metals; (3) oxygen blowing in the arc furnace.

DUPLICATING OPEN-HEARTH PRACTICE

There has been an aversion to attempting the duplication of open-hearth practice in the electric furnace because of a conviction that hot metal was "natural" for the open-hearth with its normally oxidizing atmosphere; while, on the contrary, it was an unnatural job for the electric furnace because of its neutral or reducing atmosphere. Nevertheless, experimental heats were tried over the past years, one of the earliest being made in the forepart of the war by Phelps[4]. Others tried their hand with varying results. In some plants the experiments came to one conclusion,

Total Steel Production Growth vs. Electric Furnace Production Growth

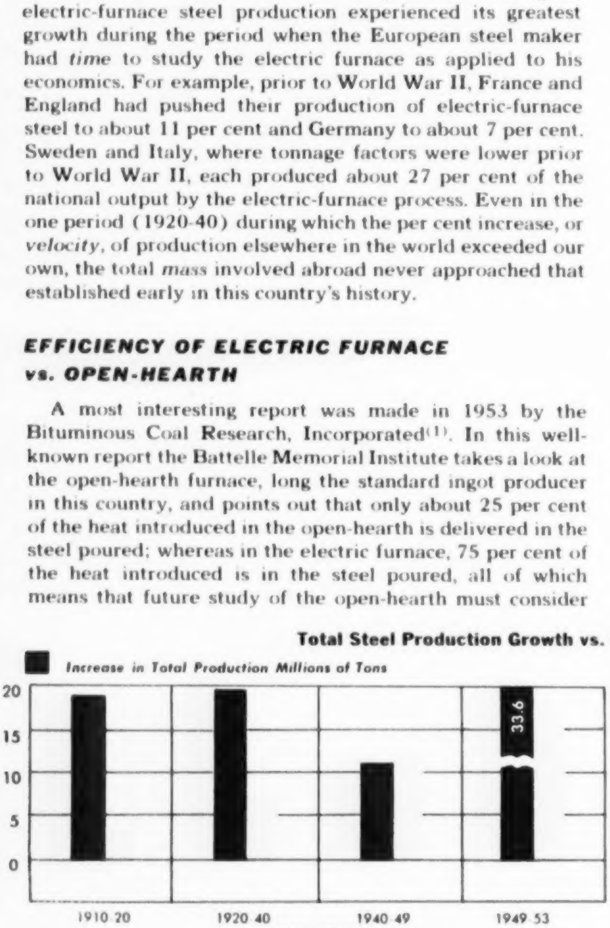


FIGURE II

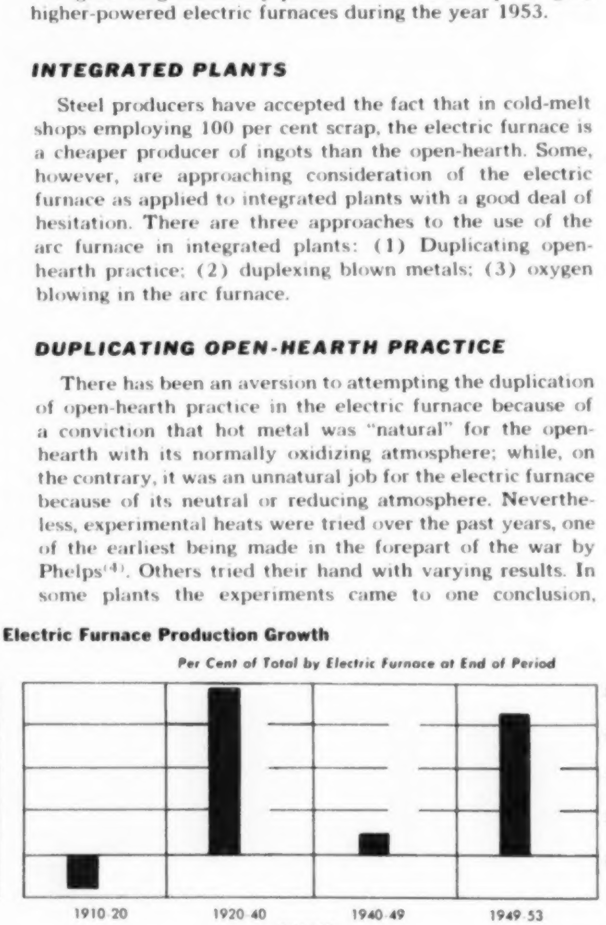


FIGURE III

namely, that while the job could be done, it was too dangerous to continue with the experimentation. They learned that, while some heats went along beautifully, the next heat might be of an explosive nature, endangering the lives of the furnace crew.

All of us recognize the fact that, in spite of the acceptance of the electric furnace as an ingot producer on a cold-metal-charge basis, the electric furnace could never be a real factor in tonnage production of ingots until there was developed a repetitive practice on hot metal.

In one plant in this country the use of hot metal in the arc furnaces has been continuous in regular production, starting with 25 per cent hot metal in the charge, gradually increasing to 40 per cent, where it now stands because of the limited availability of hot metal in the shop. We have been assured that on the 40 per cent hot-metal charge, practice has been standardized with all crews to the point where it is normal daily operation with exact control of the process. It can be said, in general, that there is found to be no saving in power or electrode consumption with this practice, but there definitely is a 10 per cent increase in the hourly rate of production of the furnace. Those in charge feel that there will be no difficulty in advancing the percentage of hot metal on regular repetitive practice to 50 per cent of the charge whenever the hot-metal supply is available in the shop. It is interesting to note that in a plant being built abroad, the installation is based upon the use of hot metal at 60 per cent of the electric-furnace charge.

The second doorway for the electric furnace into the integrated plant is that of duplexing. Duplexing of low carbon metal was used during World War I for the production of some types of alloy steel. It has been used on the Continent for years in converters for the production of various types of steels.

HEAT BALANCE OF OPEN-HEARTH FURNACE OPERATING ON A COLD-METAL CHARGE

(25 per cent pig iron, 75 per cent steel scrap)

	Btu per ton of ingots	Per Cent
	INPUT	
1. Heat combustion of fuel	4,600,000	94.0
2. Sensible heat in fuel	115,000	2.4
3. Heat content in liquid pig iron	....	...
4. Exothermic reactions	175,000	3.6
Total	4,890,000	100.0
	OUTPUT	
5. Heat content of liquid steel	1,260,000	25.8
6. Heat content of slag	186,000	3.8
7. Calcination of limestone	....	...
8. Reduction of iron ore	43,000	0.9
9. Evaporation and heating of water in charge	420,000	8.6
10. Loss in stack gases	1,340,000	27.4
11. Heat dissipated in cooling water	260,000	5.3
12. Loss through walls, radiation, etc.	1,381,000	28.2
Total	4,890,000	100.0

FIGURE IV

OXYGEN CONVERTER

Recently, there has been developed in Austria a type of operation fitted for the production of common-quality steels, namely, the Linz-type, top-fired oxygen converter. Insofar as ingot producers are concerned, this new tool is of immediate interest to them — in contrast to the long years involved in the arrival of the electric furnace. Though this youngster is but a few years old, two plants already are being built on this side of the water; one in the States, where the plan calls for the duplexing of the blown metal through electric furnaces; a second in Canada, where only a portion of the blown metal will be duplexed, the balance going directly to the mills.

By this time in 1955 we should have the results of the work of this lad who, still at grade school age-level, has stepped right into the tonnage ingot-production economy.

OXYGEN BLOWING IN THE ARC FURNACE

The third possibility for the electric furnace in the hot-metal field is still in the thinking stage. Assuming that this youngster from Linz has what it takes, is it or is it not possible to combine his efforts as an integral part of the electric furnace? With top-fired oxygen-blow on thirty-ton heats we know the volumetric expansion of the blow in relation to the dead-metal volume. We also know that the modern high-sideplate arc furnace has more than the required volume to accommodate the expansion. Top-charge, swing-aside-roof designs are being considered. The roof and superstructure would be rotated off the furnace, the hot metal introduced, and a second cover run over the furnace crucible to vent the fumes as well as the oxygen jets. The oxygen-jet cover is retracted from the furnace crucible upon completion of the blow, the normal roof and superstructure with the electrodes are swung back on, and the heat finished. Objections that would be raised to this plan are that the arc furnace would have to be built with interchangeable crucibles and that heavy cranes would be required on the furnace side for the removal and replacement of the lined crucibles. We can see no serious problem here, since any hot-metal transfer requires heavy cranes on the furnace side. From the furnace angle, we have for years been building arc furnaces with replaceable crucibles, with some installations of the swing-aside-roof design having as many as three furnace crucibles to each furnace superstructure. While this is presented here as being in the thinking stage as applied to 100-ton furnaces, it is interesting to note that it is already being done in smaller electric furnaces with 100 per cent hot-metal charges, top-blown with oxygen. What the cycle would be on crucible changes with 100-ton furnaces would be a matter of trial. We understand that they are getting 180 blows per lining with the thirty-ton Linz converters.

There may be other methods of approach for the arc furnace into the integrated plant, but it is quite apparent that two of these doorways will shortly be in everyday use and other methods remain for the future.

(Concluded on last page)

HEAT BALANCE OF ELECTRIC ARC FURNACE OPERATING ON A COLD-METAL CHARGE

	Kwhr Ton of Ingots	Per Cent
	INPUT	
1. Power into transformers	525	100
	OUTPUT	
2. Heat content of liquid steel	370	70.5
3. Heat content of slag	22	4.2
4. Refining reactions*	6	1.2
5. Heat content of waste gases	12	2.3
6. Heat extracted by cooling water	20	3.8
7. Electrical losses	40	7.6
8. Loss through walls, radiation, etc.	55	10.4
Total	525	100.0

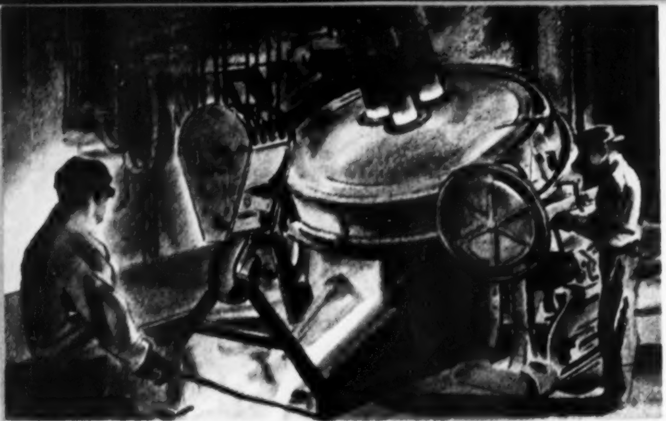
FIGURE V

*Oxidation of silicon, manganese, and phosphorous by iron ore produces heat, but oxidation of carbon by the ore is an endothermic reaction. The net effect of all refining reaction is a loss of heat.

HOURLY PRODUCTION RATES ON TOP-CHARGED HIGH-POWERED ELECTRIC FURNACES—1953

Size of Furnace	Size of Substation	Practice	Net Tons Produced Per Hour
15 ft.	12500 KVA	single slag	10.5
17 ft.	16000 KVA	" "	12.3
18 ft.	18750 KVA	" "	16.5
19 ft.	18000 KVA	" "	17.0
20 ft.	25000 KVA	" "	21.5
22 ft.	36000 KVA	" "	28.0

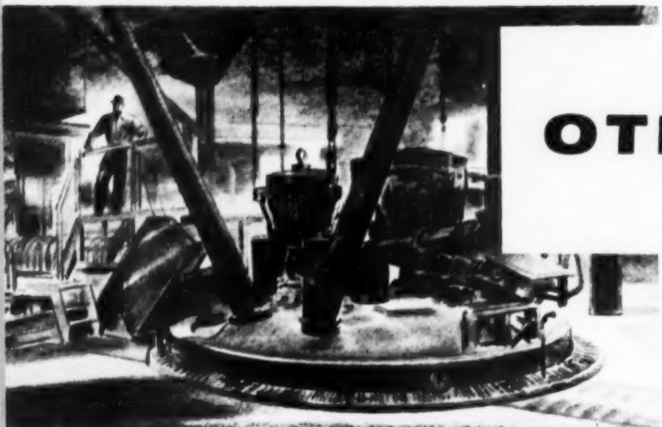
FIGURE VI



DIRECT-ARC FURNACE

AS W. B. WALLIS *observes in this issue, the open-arc furnace has long been the preferred producer of alloy and stainless steels and is currently making giant strides as a competitive source of common steels for ingot tonnage and for even the largest castings.*

Perhaps less well known to the steel industry at large are many other, power-hungry arc-furnace applications whose productive capacity and wide variety of products are felt throughout our entire economy.



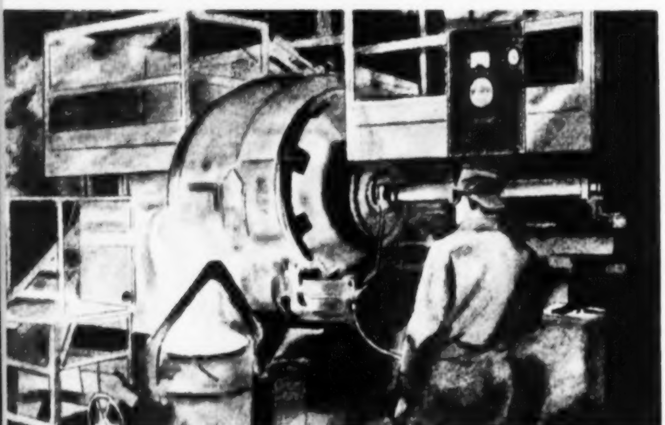
SUBMERGED-ARC PHOSPHORUS FURNACE

OTHER ELECTRIC

U. S. FERRO-ALLOY PRODUCTION—SMELTING POT OF THE WORLD

Iron and steel alloys and stainless steels are directly descended from a flourishing branch of the submerged-arc smelter — the distinguished family of ferro-alloys. U. S. producers literally scour the globe for alloy-bearing ores. Prodigious in its appetite for power and in the size of its installations, ferro-alloy production is heavily concentrated around areas of abundant, low-cost electrical "fuel."

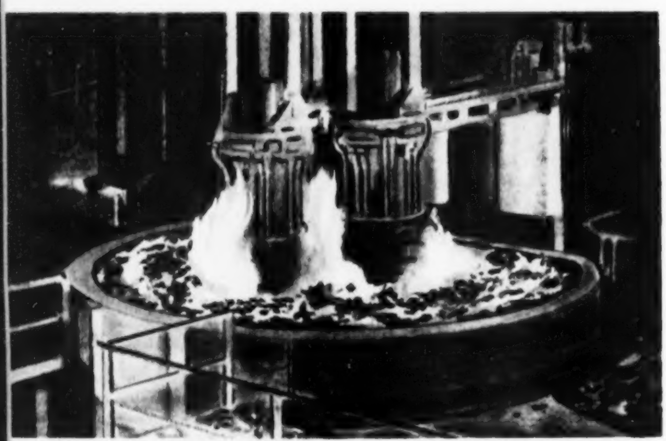
Focal points for the world's alloy-ores, these electric furnaces are, in turn, a source of alloying ingredients for ferrous and non-ferrous metals production all over the United States and abroad. The incandescence of the giant electrodes of the submerged-arc-type furnace is but a subdued fore-runner of the roaring open-arc furnace which will blend its products into mixtures of super-steels.



INDIRECT-ARC FURNACE

CALCIUM CARBIDE—LAMPLIGHTER, WELDER, CHEMICAL BUILDING BLOCK

The year: 1892. The place: Spray, North Carolina. The occasion: an abortive attempt to produce aluminum from its oxide in the "new" electric furnaces. Not aluminum, but a greyish, crystalline substance was the result of this pioneering effort. Attempting to quench



SUBMERGED-ARC FURNACE

this apparently worthless product with water, the furnaceman was rewarded with volumes of gas. Calcium carbide and acetylene were born!

Today, the submerged arc-furnace smelting of calcium carbide for acetylene production is a major industry — responsible for most of the acetylene gas used in welding, cutting and surfacing and, more recently, in the synthesis of vinyl and rubber plastics and acetic acid. Its possible future uses challenge the imagination.

today in this field. Once heavily concentrated in the TVA area, the leaps and bounds of its phenomenal growth are carrying phosphorus-furnace capacity into the power-rich, ore-heavy western U. S. and Florida. Used in vast quantities for foods, medicines, detergents and fertilizers, electric-furnace phosphorus has come a long way from the days of the strike-anywhere match . . . with more new uses in view. Who can say what new vistas of magic alchemy lie ahead?

ARC FURNACES AT WORK . . .

ABRASIVES AND REFRACTORIES—FORTUNES FROM CLAY AND KILOWATTS

To the ancients, all things were composed of four basic elements: earth, fire, air and water. Today, they would be amazed at the great *variety* of substances wrought by a conjunction of only two of their four elements — aluminous earth and the fire of the carbon arc. Given their basic tool in the Higgins arc furnace of 1904, abrasives manufacturers were quick to develop production of high melting-point materials for refractory applications, as well. Thus was born a myriad of new and useful products in the creative inferno of the electric arc.

PHOSPHORUS—ALWAYS SOMETHING NEW

All phosphorus is manufactured; it is never found by itself in Nature. Two generations ago, the entire world's production of elemental phosphorus did not exceed 400 tons. Today, this country uses ten times that amount for safety matches alone — a dim flicker in the light of an industry which is continually responding to the development of new processes and applications.

Unlike some of its earlier, easy victories over alternative methods of manufacture, the electric arc furnace competed vigorously with blast-furnace production of phosphorus for 27 years (1910-1937) before establishing the clear-cut advantage it holds

NON-FERROUS MELTING & REFINING—NEW LOOK AT AN OLD ART

Electric-furnace melting and refining of non-ferrous metals and their alloys are rapidly increasing. As in the fields of iron and steel production, electric-furnace methods of copper and aluminum melting and refining have had to face the task of winning general acceptance over historic, fuel-fired practices. Nevertheless, a growing percentage of all non-ferrous castings is poured from electric furnaces. In addition, a large share of this country's non-ferrous *refining* operations are now carried out in either direct or indirect-arc furnaces as contrasted with the universally accepted reverberatory-furnace procedure of a few years ago. Here, then, is another principal industry in which the electric arc furnace adds current events to a history almost as old as the written word.

IN SUCCEEDING ISSUES OF CARBON AND GRAPHITE NEWS...

Future issues of CARBON AND GRAPHITE NEWS will bring you contributions from recognized authorities among furnace and equipment manufacturers, consultants, metallurgists and producers.

Watch For Them . . .
And Let's Have Your Comments!

There is no question that, just as the electric furnace has at long last arrived in the cold-metal field, it will be very much in the picture in future integrated plants.

FLEXIBILITY

Finally, the electric furnace is most flexible. It is not limited to continuous operation once it has been put under fire. It can be shut down and restarted at will. It is ideally adapted to the forty-hour week and requires no special arrangement for crews over holidays.

QUALITY CONTROL AND THE NEW MARKET

We have, for too long a time, enjoyed a seller's market; in fact, it has been the longest seller's market of any period in the steel industry. We are now entering a buyer's market which, after all, is but a return to normalcy. Many of us will have to refurbish some of the tools in selling our products that were in everyday use twenty to twenty-five years ago. Unfortunately, those sales tools that we used so well in the period of the '30s are just not going to work in the buyer's market ahead. The buyer in the saddle is, of course, going to insist upon quality as he always has. He is going to draw his specifications a little finer due to the expansion of metallurgical knowledge within the industry, but one factor that has got to be kept in mind is that he has at hand many new tools for the checking of these factors of quality in specification that were not heretofore available.

Looking forward, we can see no relaxation in specifications on qualities of even the most common steels. The electric furnace is the tool that can best fulfill the requirements of this future buyers' market demand.

ELECTRIC FURNACES IN THE FOUNDRY

To turn for the moment to the foundry industry in the United States, the electric furnace has long been accepted for the production of small castings. The vast majority of the jobbing steel foundries in the United States are so operating. In this branch of the industry, acceleration (MV^2) was not too high for the youngster to get aboard years ago.

The field of large-casting production presents a problem for the electric furnace. While it is just as true that the steel foundryman cannot produce molten metal with his open-hearth furnace for as little money as he can with an arc furnace, he has further problems to consider. There has been for a long time a conviction on the part of foundrymen that on large castings they could not make as high-quality castings with electric furnaces as they could with open-hearths. This conviction has been hard to disprove for the very simple reason that we have no large electric furnaces making large castings in steel foundries in the United States. However, foundrymen who do have furnaces making relatively small twenty-five-ton heats in foundries have satisfied themselves on this one point.

There still remains another problem. If the foundryman matches his open-hearth, size for size, with an arc furnace and, per se, the size of the largest casting, he is then faced with the fact that he has twice as much metal production from the electric as he has been obtaining from the same size open-hearth. In other words, more metal than he can use.

Recently, in the production of large castings, some foundrymen in this country, as in Europe, have been making these large castings in sections, machining them, shipping them to site, and there welding them into the large integral unit desired. This practice is relatively new and, once developed, has many advantages. First, it cuts down tremendously the flask expense and handling expense, both in the foundry and the machine shop, and cuts down the cost of special transport to site. This practice, fully developed, will enable the foundryman — where he is using a 100 ton open-hearth — to apply a fifty-ton electric for not only the production required but also for the largest-size casting needed.

THE FUTURE

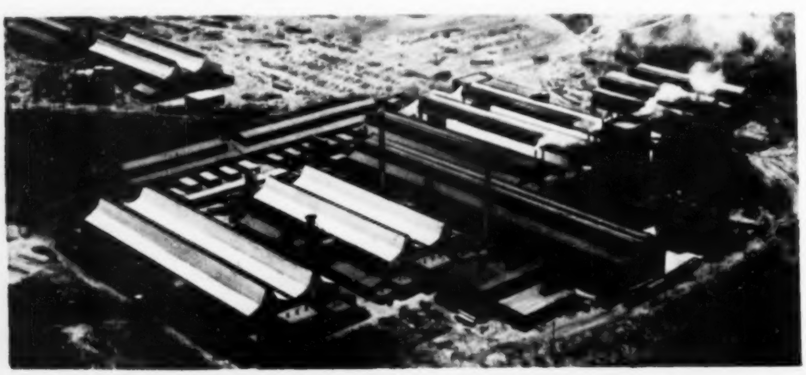
There was a time at the end of World War II when we felt we had arrived at the end of the road; that we had installed more electric furnaces than the industry could absorb and that our activities would henceforth be limited to resale and relocation of equipment that had been applied to war use. The expansion period between 1949 and 1953 was, therefore, a most welcome and highly exhilarating rebuttal to that feeling.

The electric furnace now has been with us forty-eight years — years of progress that was slow because a deep and firm foundation of proven performance was being built. If one could project the data over the next forty-eight-year period, to the year 2002 — perhaps open-hearths might be hard to find.

References

1. *Comparative Economics of Open-Hearth and Electric Furnaces for Production of Low-Carbon Steel.* A technical and economic study sponsored at Battelle Memorial Institute by Bituminous Coal Research, Inc., and fourteen electric utility companies.
2. Reinartz, L. F., *Electric Furnace vs. Open-Hearth Furnace in Cold Metal Shops.* Regional Technical Meeting of the American Iron and Steel Institute, Philadelphia, December, 1953.
3. King, C. D., *Steelmaking Processes — Some Future Prospects.* Howe Memorial Lecture, New York Meeting, A. I. M. E., February, 1954. Published in Journal of Metals, April, 1954.
4. Phelps, H. F., Consulting Engineer.

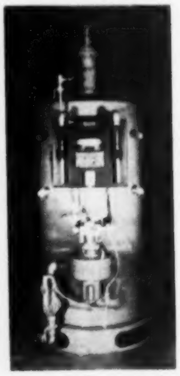
WILLIAM B. WALLIS *graduated from The Pennsylvania State College in 1911 and first became interested in arc furnaces in 1913 while working for a public utility company in western Pennsylvania. By 1915, he had gone actively into the building of arc furnaces and has continued that work to date. By 1936 he was concerned with the introduction of arc furnaces into the copper industry and in 1937-38 was consulting engineer on the first large six-electrode smelting furnace installed in Europe. His major activity has been in building electrical arc furnaces for the steel industry.*



impervious to moisture, arc radiation and mechanical abuse. The material is molded with longitudinal grooves that give a firm grip and resistance to twist.
For further information circle No. 661 on literature request card on p. 32-B.

Gas Generators

A new endothermic gas generator for controlled atmosphere furnaces has been announced by Ipsen Industries, Inc., It produces 1250 cu. ft. per hr. Atmospheric air and raw gas are drawn through flow meters, accurately proportioned and pumped into a catalytic cracking retort heated with multiple jet burners. As soon as completely cracked in the heating chamber, the gases are cooled by a water jacketed heat exchanger. Natural gas, butane, propane, and certain manufactured gases can be processed. Several safety features are provided, including an automatic firecheck in the event the operating gas pressure falls below normal and a gold fuse and thermocouple to assure operation within a safe temperature range. Two exhaust vents at the top provide for efficient removal of combusted fuel gas. A water-cooled heat exchanger cools the endothermic gas as it leaves the generator, eliminating carbon deposition.



For further information circle No. 662 on literature request card on p. 32-B.

Phosphate Coating

A new phosphatizing compound for zinc has been announced by the Pennsylvania Salt Mfg. Co. This compound provides a fine crystalline coating on metal surfaces which serves as a base for subsequent painting operations. It is mixed with water and applied by spraying. While designed for use on zinc surfaces, Fosbond 61 may also be used on steel.
For further information circle No. 663 on literature request card on p. 32-B.

Portable X-Ray

A new line of portable industrial X-ray equipment has been announced by Balteau Electric Corp. The self-contained X-ray head of the model rated at 195 kv., 5 ma., weighs only 153 lb. and measures 26½ by 14 by 8¼ in. The head houses both X-ray tube and high-voltage transformers of radical new design. All models operate directly from 110 or 220-volt, 60-cycle lines and do not require cooling pumps or special accessories.
For further information circle No. 664 on literature request card on p. 32-B.

Zirconium Oxide

Production of pure zirconium oxide has been announced by Zirconium Corp. of America. Pure zirconium oxide is useful where extreme purity is required for chemical reactions, as a starting material for all zirconium chemicals and as a polishing agent. Pure zirconium oxide having a monoclinic crystal structure is not to be used in formed parts. It is claimed that this pure oxide will have the finest grain size available. Spectographic analyses show it to be 99.2% pure.
For further information circle No. 665 on literature request card on p. 32-B.

Aluminum Solder

Aluminum solder in wire form has been announced by Belmont Smelting & Refining Works. Two alloys are available — No. 60, with a melting point of approximately 650° F.,

and No. 40, with a low melting point of approximately 400° F. The wires are extruded in diameters of 1/16, 3/32, and ⅛ in. on 5 lb. spools. The wire permits application in close working areas and mechanical aluminum soldering operations.

For further information circle No. 666 on literature request card on p. 32-B.

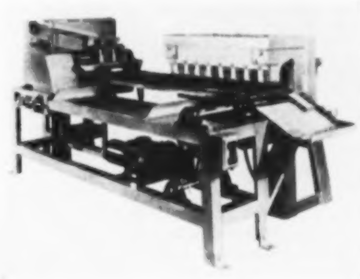
Tumbling Compounds

A new line of media-compound combinations for producing high lustre finishes by dry tumbling methods has been announced by Tumb-L-Matic, Inc. The new materials were designed for finishing small metal parts such as jewelry findings, fragile stampings, screw machine parts, wire and other forms made of rolled gold, silver, nickel, chromium, copper, brass and stainless steel. The compounds consist of treated granules, obtainable in various sizes. The slight residue left on the parts after processing can be wiped or washed off. The granules, in turn, can be restored to their original effectiveness by the addition of a special cream.

For further information circle No. 667 on literature request card on p. 32-B.

Bar Heating

End heating of bar stock for upsetting is now completely automatic due to a mechanical development announced by Gas Appliance Service. This consists of a mechanical hopper-feed unit, mounted at one end of the furnace conveyor. Bars are then car-

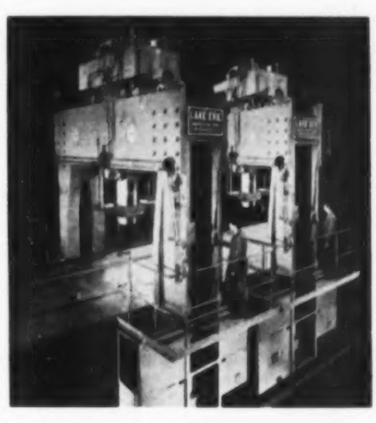


ried through the heat zone at a speed to satisfy the desired heating cycle. The production capacity of this equipment, based on a Model 10-D Roto-Flame furnace with a 39 in. heat zone and heating 2 in. of the end of ⅝ in. stock, is 600 pieces an hour.

For further information circle No. 668 on literature request card on p. 32-B

Straightening Press

An unusual hydraulic press built by Lake Erie Engineering Corp. is used to straighten castings 22 by 10 ft. and weighing over 46,000 lb. The press has an overall length of 40 ft., width of 23 ft., height 30 ft. and weighs over 1,000,000 lb. Twin traveling heads deliver 1000 tons force



by means of a 5000 psi. pump and a 50 hp. motor. Individual carriages allow independent longitudinal movement and each traveling head can be transversely positioned to meet requirements. Each of these operations is accomplished at 120 in. per minute by separate gear motors.

For further information circle No. 669 on literature request card on p. 32-B

WHAT'S NEW

IN MANUFACTURERS' LITERATURE

693. Air-Gas Mixer
Bulletin L-700 gives engineering and application data on air-gas proportional mixer. *Eclipse Fuel Eng'g*

694. Allowable Stresses
Data Card 154 gives max. allowable stress values for 22 types of steel tubing. Formulas for calculation of max. working pressures. *Babcock & Wilcox*

695. Alloy Castings
8-page bulletin on alloy castings for heat treating. *Ohio Steel Foundry*

696. Alloy Steel
68-page "Aircraft Steels" includes revised military specifications. Also stock list. *Ryerson*

697. Alloy Steel
32-page book on abrasion resisting steel. Properties, fabricating characteristics, uses. *U. S. Steel*

698. Alloy Castings
22-page bulletin 2041 on heat and corrosion resistant castings. *Blaw-Knox*

699. Aluminum Alloy
8-page bulletin on Ternalloys, high-strength aluminum base alloys, gives composition, properties, castability, machinability, welding and brazing. *Apex Smelting Co.*

700. Aluminum Forgings
Booklet describes facilities for aluminum extrusion and forging. *Bridgeport Brass*

701. Aluminum Melting
Folder on electric furnaces for the aluminum alloy foundry. *Ajax Engineering*

702. Ammonia Atmospheres
12-page bulletin B-52 on dissociated ammonia furnace atmospheres. *Drever*

703. Annealing Furnace
Folder on cover-type annealing furnace. *Continental Industrial Engineers*

704. Arc Welding
New 16-page catalog on equipment and accessories for tungsten arc welding process. *Air Reduction Sales Co.*

705. Atmosphere Furnace
Information on mechanized batch-type atmosphere furnaces for gas cyaniding, gas carburizing, clean hardening or carbon restoration. *Dow Furnace*

706. Atmosphere Furnace
Reprint on bright annealing of copper in atmosphere furnace. *Holcroft*

707. Barrel Finishing
52-page book on barrel finishing, deburring and finishing equipment and compounds. *Almco Division*

708. Barrel Finishing
32-page handbook on compounds for descaling, deburring, coloring, metal cleaning and rust inhibition. *Lord Chem.*

709. Be-Cu, Wrought
"Applications Unlimited", collection of case histories on successful uses of wrought beryllium copper. *Beryllium Corp.*

710. Bearings
27-page bulletin, S-53, on self-lubricating bronze bearings, core and bar stock. *Amplex Division*

711. Bending
Catalog on presses for bending, forming, blanking, drawing and multi-punching. *Cleveland Crane & Engineering*

712. Bending and Cutting
Folder describes hand and air-operated bender-cutter and its applications. *J. A. Richards*

713. Bimetal Applications
36-page booklet, "Successful Applications of Thermostatic Bimetal", describes 22 uses and gives engineering data. *W. M. Chace*

714. Black Oxide Coatings
8-page booklet on black oxide coatings for steel, stainless steel and copper alloys. *Du-Lite*

715. Black Oxide Finish
Folder on penetrating black finish for ferrous metal. *Puritan Mfg.*

716. Blast Cleaning
New 24-page catalog 1210 on equipment and accessories for blast cleaning and dust control. *Pangborn*

717. Blowers
Bulletin 100-53 on combustion air blowers of 8 to 20 oz. pressures. *Western Products*

718. Brazing
Bulletin 5889 on furnace and induction brazing installations and methods. *General Electric*

719. Brazing Applications
48-page manual on all aspects of silver brazing applications and problems. *American Platinum Works*

720. Brazing Stainless Steel
Illustrated booklet, "Bright Annealing, Hardening and Brazing Stainless Steel", describes conveyor furnace and bright brazing alloy. *Sargeant & Wilbur*

721. Bright Carburizing
Job data on bright carburizing and hardening gears. *Ipsen*

722. Bronze
Folder gives tables of properties, uses, forms and other data on phosphor bronzes. *Chase Brass & Copper Co.*

723. Bronze Bearings
New brochure on bearing bronze. *American Smelting and Refining Co.*

724. Burners
Catalog No. C6A on gas burners. *American Gas Furnace*

725. Burners
8-page reprint No. 43 on Method for Improving Temperature Uniformity in Furnaces. *North American Mfg.*

726. Carbides
84-page catalog of sintered carbides, hot pressed carbides, cutting tools, drawing dies, wear resistant parts. *Metal Carbides*

727. Carbon Steel Castings
Data folders on four types of carbon steel castings. Composition, properties, hardenability bands, uses. *Unitcast*

728. Carbonitriding
Literature on Ni-Carb (carbonitriding) treatment for surface hardening. *American Gas Furnace*

729. Casehardening
32-page booklet on casehardening of steel by nitriding. *Armour Ammonia Div.*

730. Cast Iron
Guide to the selection of engineering cast irons. *International Nickel*

692. Zirconium
"Facts about Zirconium" is a 64-page book about the history and production of zirconium. It gives mechanical, physical and chemical properties. Melting,

forging, rolling, welding, machinability of zirconium are also discussed. A generous appendix and a list of 72 references to publications on zirconium are also included. *Carborundum Metals Co.*

731. Castings, Bronze
16-page booklet on sand and centrifugal castings. *American Non-Gran Bronze*

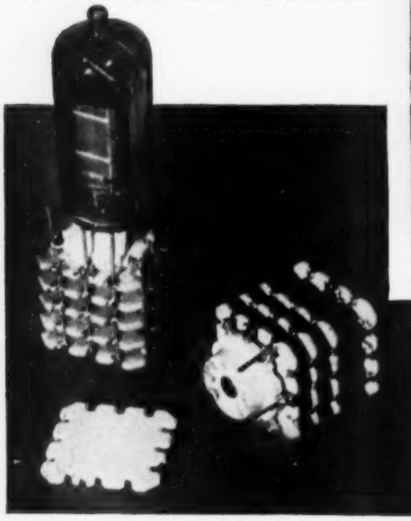
732. Ceramic Coatings
New brochure on ceramic coatings for protecting metals from heat and corrosion. *Solar Aircraft Co.*

733. Ceramic Coatings
8-page bulletin on ceramic coatings for high temperatures. Their advantages on steel and aluminum. *California Metal Enameling Co.*

734. Chromate Coatings
Folder gives characteristics and uses of chromate conversion coatings on nonferrous metals. *Allied Research*

735. Chromium-Nickel Alloy
4-page bulletin on 25% Cr. 12% Ni cast alloy. *Standard Alloy*

Another Norton ℞ on the job!



On Project Tinkertoy, ceramic wafers containing barium titanates are fired at 2600°F. The ℞ for this job is setter plates of Norton FUSED STABILIZED ZIRCONIA. These plates *engineered* to withstand the effects of the very reactive titanates and to make repeated trips to the electric furnace for 9-hour firing cycles — have proved to be most practical for firing titanates.

◀ ***Completed Modules*** made entirely automatically by the Tinkertoy process, with a ceramic wafer containing titanates ready for firing on Norton FUSED STABILIZED ZIRCONIA setter plates.

Project Tinkertoy,† revolutionary method of producing electronic circuits, uses Norton setter plates

Project Tinkertoy, developed by the National Bureau of Standards and sponsored by the Navy's Bureau of Aeronautics, is designed to produce complete electronic units automatically. The Project is in full swing at a pilot plant in Arlington, Va., operated for the government by the Kaiser electronics division of the Willys Motor Co. According to cost experts the new "push-button" method is cutting production costs approximately 40%!

Standard "building blocks" used in the new system are ceramic wafers, mechanically produced and assembled into modules, which replace the complicated mazes of wiring characteristic of conventional electronic equipment.

The Norton ℞ For Tinkertoy

Firing of the Tinkertoy ceramic wafers — in electric furnaces at 2600°F — is an important processing step. For firing wafers containing barium titanate elements, the refractory setter plates selected are made of Norton FUSED STABILIZED ZIRCONIA.

This Norton-developed refractory material has been especially *engineered* to provide inertness, cleanliness, and long life. It is *prescribed* for many similar applications to provide maximum efficiency at high temperatures.

For firing steatites, Norton prescribes CRYSTOLON* setter plates, a highly unreactive and oxidation-resistant silicon carbide refractory material. And for electric furnaces and kilns the ℞ is CRYSTOLON heating elements — "Hot Rods" — with a proved capacity for 2 to 4 times longer service life.

For further facts on the refractory materials *you* need to improve and economize your processing, call in your Norton Refractories Engineer. Or write direct for literature to NORTON COMPANY, 327 New Bond St., Worcester 6, Mass. *Canadian Representative:* A. P. Green Fire Brick Co., Ltd., Toronto 5, Ontario.

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†Now known as "Modular Design of Electronics and Mechanized Production of Electronics."

736. Clad Metals
24-page booklet on principles of bonding, characteristics of clad metals, methods of cladding and applications. *Superior Steel*

737. Cleaner
Folder gives data on metal cleaners for use with water in still-tank or spray-washing equipment. *Solventol*

738. Cleaning
Data sheets on acid activators to promote removal of scale and oxides from steel and iron. *Swift Ind. Chem.*

739. Cleaning Aluminum
12-page bulletin on cleaning process for preparing aluminum and magnesium for welding. *Northwest Chemical*

740. Cleaning Compound
Bulletin B-6 on water displacing compound for producing unspotted, dry surfaces. *Apothecaries Hall*

741. Cold Finished Bars
Catalog of carbon and alloy steel bars. *Monarch Steel*

742. Combustion Control
20-page booklet on combustion of various fuels and portable instrument to measure content of oxygen and combustibles. *Cities Service Oil*

743. Controlled Atmospheres
24-page bulletin describes production problems with reference to dry atmospheres. *Pittsburgh Lectrodryer*

744. Copper Alloys
New 48-page book contains tables of alloys with composition, typical uses, general, working, mechanical, electrical properties, hardness, ASTM specification numbers. *Revere*

745. Copper Alloys
New technical data book on phosphor bronze and nickel silver. *Seymour Mfg.*

746. Copper Tubing
24-page booklet on uses and properties of copper water tube, dryseal tube, red brass and copper pipe. *Revere*

747. Corrosion of Copper
28-page booklet B-36 discusses corrosive attack on copper and copper alloys. Tabulation of their relative corrosion resistance. *American Brass*

748. Corrosion Resistance
35-page booklet on plastic materials of construction. *Atlas Mineral Products*

749. Corrosion Resistant Linings
Booklet on acid and alkali-proof cements, linings and coatings for pickling tanks, chemical equipment and other uses. *Electro Chemical Eng. & Mfg.*

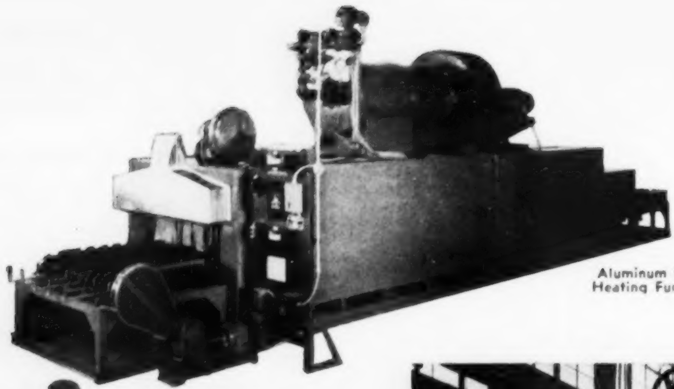
750. Cut-Off Wheels
Folder gives data, operating suggestions and grade recommendations of cut-off wheels. *Manhattan Rubber Div.*

751. Cutting Fluid
Data on nonflammable, nonexplosive chemical for tapping, pipe threading, drill press work, lathe cutting, etc. *Easy-Cut Mfg.*

752. Deep Drawing
Reprint on new deep drawing technique involving single-stroke dies and eliminating intermediate operations. *Schnell Tool & Die*

753. Degreasing
40-page book on properties and use of trichlorethylene. Methods of handling and safety measures. *Niagara Alkali*

754. Design of Dies
32-page bulletin on design of dies for upset forging. Also rules for upsetting and examples of forgings. *Ajax Mfg.*



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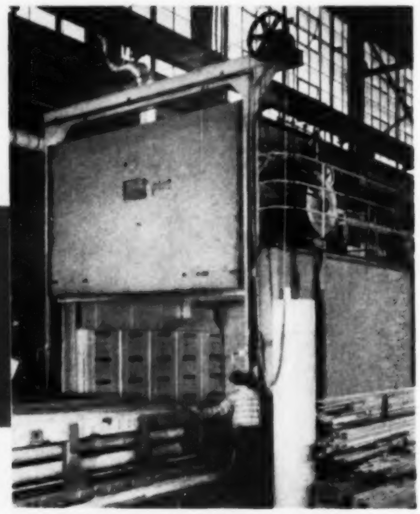
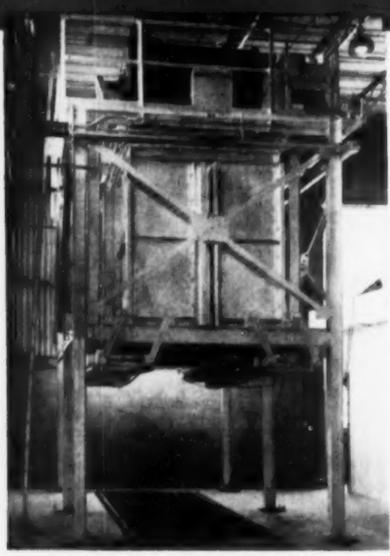
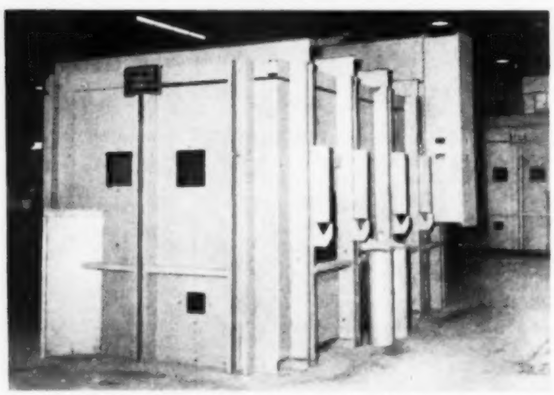


Convection Car Bottom Furnaces for Aluminum Billets—Electric, Gas or Oil.



Solution Heat Treat Furnaces (Electric) for the Aluminum and Aircraft Industries. (Furnace shown above installed in large Aircraft Plant.)



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755. Electric Furnaces
8-page booklet on belt conveyor electric furnaces for bright hardening. *Westinghouse Electric Corp.*

756. Electroplating
8-page bulletin on rectifiers for cleaning, polishing, electroforming, electroplating and anodizing. *Ther Electric & Machine Works*

757. Enamel Finishes
Data on Plextone multicolored enamels includes colors, spray equipment, technical tips. *Maas & Waldstein*

758. Extensometer
8-page bulletin on extensometers for sheet metal and wire, compressometers, defectometers and other accessories. *Baldwin-Lima-Hamilton*

759. Extrusion
16-page bulletin on Koldflo extrusion of parts in one operation. Step-by-step procedure. *Mullins Mfg. Corp., Koldflo Div.*

760. Extrusion Presses
8-page bulletin on presses designed for extrusion of aluminum, brass and other nonferrous metals. *Lake Erie Engineering*

761. Fatigue of Magnesium
18-page paper, "Plastic Flow and Work Hardening Phenomena in Magnesium Alloys During Fixed-Deflection Fatigue Tests." *Dow Chemical*

762. Ferro-Alloys
32-page book tells how ferro-alloys are made and how they are used. *Electro Metallurgical Co.*

763. Filters
New 4-page special report of a central filtration installation at Warner & Swasey's New Philadelphia, Ohio, plant. *Industrial Filtration*

764. Finishing
Six bulletins describing finishing compounds for stainless steel, aluminum, other metals. *Apothecaries Hall*

765. Finishing
Catalog A-654 gives complete story on planning industrial finishing systems and shows many installations of cleaning and pickling machines. *R. C. Mahon*

766. Finishing
28-page catalog, B-9, on corrosion-resistant baskets, racks, crates and tanks and other fixtures for cleaning and finishing. *Rolock*

767. Flame Cleaning
20-page bulletin (ADR 20) on flame cleaning process for steel ships, costs and equipment. *Air Reduction Sales*

768. Flame Hardening
20-page booklet on precision flame hardening machine with electronic control. Details of operation and applications. *Cincinnati Milling Machine*

769. Flame Plating
16-page booklet lists advantages, properties, specifications of flame-plated tungsten carbide coating. *Linde*

770. Flaw Detection
Illustrated bulletin on Spotcheck, new dye-penetrant method for locating surface defects. *Magnaflux*

771. Flow Meters
24-page manual on application and installation of indicating flow meter. *Meriam Instrument*

772. Flow Meters
Bulletin 201 on flow meter for gas used in heat treating. *Waukee Eng'g.*

773. Forgings
Handsome 32-page brochure on large forgings for turbine shafts, rotors, drop hammer anvils, rolls. *U. S. Steel*

774. Forgings
94-page book on die blocks and heavy-duty forgings. 20 pages of tables. *A. Finkl & Sons*

775. Foundry Equipment
New 16-page bulletin on various models of mold and core machines, their operation and installation. *Beardsley & Piper*

776. Freezer
8-page folder on portable freezer, 110-volt a.c., operating to -180° F., for shrink fitting, hardening, stabilizing and testing. *Webber Mfg.*

777. Furnace Controls
22-page booklet on instruments and controls for heat treating furnaces. *Hays Corp.*

778. Furnace Fixtures
16-page catalog on baskets, trays, fixtures and carburizing boxes for heat treating. 66 designs. *Stanwood Corp.*

779. Furnaces
Bulletin 435 on furnaces for tool room, experimental or small batch production. Gas, Oil, electric. Muffle or direct heated. *W. S. Rockwell*

780. Furnaces
High temperature furnaces for temperatures up to 2000° F. are described in bulletin. *Carl-Mayer Corp.*

781. Furnaces
Bulletin describes 18 electric furnaces for research and small-scale production, with operating temperatures to 3000° F. *Harper Electric Furnace*

782. Furnaces
32-page catalog on high-speed gas furnaces for heat treating carbon and alloy steels; also pot furnaces for salt and lead hardening. *Charles A. Hones*

783. Furnaces
12-page brochure on car furnaces of special and conventional design. *Jet Combustion*

784. Furnaces, Heat Treating
Catalog on furnaces for tool room and general purpose heat treat. *Cooley*

785. Furnaces, Heat Treating
Bulletin on fuel and electric furnaces for heat treating. *Dempsey*

786. Furnaces, Heat Treating
12-page bulletin on conveyor furnace, radiant tube gas heated, oil or electrically heated. *Electric Furnace Co.*

787. Furnaces, Heat Treating
Bulletin on furnaces for annealing, normalizing, hardening, tempering, forging. *Flinn & Dreffein Eng'g*

788. Gamma Radiography
Data file on equipment and sources for cobalt 60 radiography in industry. *Technical Operations*

789. Gold Plating
Folder on salts for bright gold plating. Also lists equipment needed. *Sel-Rex*

790. Graphite Electrodes
Vest-pocket notebook containing 90 pages of information on electric furnace electrodes and other carbon products. *Great Lakes Carbon Corp.*

791. Graphite Molds
Data on two types of molds for casting magnesium, steel, copper, brass and other metals. *National Carbon*

792. Graphitic Tool Steels
48-page booklet on heat treating data, properties and 46 specific applications of graphitic tool steel. *Timken*

793. Graphitization
12-page booklet discusses graphitization from the standpoint of temperature,

chemical composition, deoxidation practice, pre-welding microstructure, welding conditions, post-weld heat treatment, stress and strain. *Edward Valves*

794. Grinding Oils
16-page booklet on seven grinding oils. Suggestions for handling grinding oils. *D. A. Stuart*

795. Grinding Wheels
New 38-page catalog on reinforced resinoid grinding wheels gives applications, wheel sizes, operating speeds and other data. *Norton*

796. Handling Devices
Pamphlets on clamps for lifting and handling. Their application to various industries. *Merrill Bros.*

797. Hardness Tester
Literature on Brinell testing machines. *Detroit Testing Machine Co.*

798. Hardness Tester
20-page book on hardness testing by Rockwell method. *Clark Instrument*

799. Hardness Tester
Bulletin ET 469 on new portable hardness tester. *Newage International*

800. Hardness Tester
13-page booklet on microhardness tester with optional Vickers or Knoop diamond. *Geo. Scherr*

801. Hardness Testers
20-page bulletin on models, applications and how to use superficial hardness testers. *Wilson Mechanical Instrument*

802. Hardness Testing
8-page catalog B-953 on principles and standards of Brinell hardness testing, and types of machines. *Steel City Testing Machines*

803. Heat Resistant Castings
New Bulletin No. 5 on heat and corrosion resisting pots, tubs, boxes. *Standard Alloy*

804. Heat Resistant Finish
Bulletin 531 on silicone-base heat-resistant finish. *Midland Ind. Finishes*

805. Heat Treat Baskets
12-page bulletin on wire mesh baskets for heat treating and plating. *Wiretex*

806. Heat Treat Belts
Catalog of conveyor belts and data for their design, application and selection. *Ashworth Bros.*

807. Heat Treat Control
Data sheet No. 5.2-6 on annealing cover temperature control systems. *Minneapolis-Honeywell*

808. Heat Treating
Folders on steam method of hardening and tempering. Case histories. *Leeds & Northrup*

809. Heat Treating
Bulletin 14-T on ovens for heat treatment of aluminum and other low-temperature processing. *Young Bros.*

810. Heat Treating
Bulletin 200 on car hearth, rotary hearth, pit, roller hearth, belt, chain, pusher, "hi-head" furnaces. *R-S Furnace*

811. Heat Treating
Selector for heat treating baskets, trays, carburizing boxes, retorts and miscellaneous fixtures. *Stanwood Corp.*

812. Heat Treating
Catalog on HeaTreaT furnaces gives applications and performance features. *Heat Treating Supply Co.*

813. Heat Treating
Data on how to heat, quench, wash and temper automatically. *Metalwash Machinery*


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24-page catalog on heat and corrosion-resistant equipment for heat treating and chemical processing. 30 classifications of equipment. *Pressed Steel*

815. Heat Treating Stainless
84-page book on heat treating stainless steels, both martensitic and austenitic. *Republic Steel*

816. Heating
Bulletin SC-166 on furnaces for forming, annealing and other processes. *Surface Combustion Corp.*

817. Heating Elements
24-page Bulletin H on electric heating elements. Includes extensive tabular data on physical and electrical specifications for various sizes. *Globar Div.*

818. High-Alloy Castings
Bulletin 3150-G on castings for heat, corrosion, abrasion resistance. *Duraloy*

819. High Speed Steel
New bulletin on structure and properties of "desegatized" high speed tool steel. *Latrobe*

820. High-Temperature Alloy
Property data for 21% Cr, 9% Ni heat-resistant alloy. *Electro-Alloys Div.*

821. High-Temperature Belts
24-page bulletin on metal conveyor belts. *Wickwire Spencer*

822. High-Tensile Steel
Bulletin on nickel-copper steel of low-alloy, high-strength type. *Youngstown Sheet and Tube*

823. High-Vacuum Furnaces
12-page brochure No. 790 on vacuum furnaces for melting and casting titanium, zirconium, germanium, copper, iron and steel. Also furnaces for annealing, hardening, brazing. *F. J. Stokes*

824. Hydrogen Atmosphere
Bulletin on equipment for supplying hydrogen with oxygen content less than one part per million and dew point to -70° F. *Baker & Co.*

825. Identifying Alloys
Booklet of procedures for rapid identification of more than 125 metals and alloys. *International Nickel*

826. Immersion Pyrometer
Catalog No. 155 on new immersion pyrometer. *Pyrometer Instrument Co.*

827. Impact Testing
Bulletin on machine for Izod, Charpy and tension testing. *Riehle*

828. Induction Heating
"Induction Heating" . . . presents case histories of increased production, reduced space, lower costs. *Westinghouse*

829. Induction Heating
4-page brochure on high frequency induction heaters for heating to 3000° F. *Electric Arc, Inc.*

830. Induction Heating
Bulletin 1440 on system for safety control of induction heating through use of components built into every unit. *Lindberg Engineering*

831. Induction Heating
60-page catalog tells of reduced cost and increased speed of production on hardening, brazing, annealing, forging or melting jobs. *Ohio Crankshaft*

832. Induction Melting
Data on induction melting furnaces for aluminum, brass and copper. *Morrison Engineering*

833. Inert Gas Welding
Heliwelding, inert-gas-shielded arc-welding process for all-position welding

of aluminum, magnesium, stainless steel, brass and copper, in ADC-709, Catalog 9. *Air Reduction*

834. Input Controller
Bulletin on instrument for straight-line furnace temperature control. *Winslow Co.*

835. Iron-Nickel Alloys
32-page bulletin on austenitic iron-nickel alloys having special thermal expansion or thermo-elastic characteristics. *International Nickel*

836. Iron Powder
Bulletin on production of iron powder for flame cutting, scarfing, powder metallurgy, electronics and chemical applications. *Easton Metal Powder Co.*

837. Laboratory Furnaces
Data sheets on complete line of laboratory furnaces for metallurgical operations. *Boder Scientific*

838. Leak Detector
16-page bulletin on leak detector for location and measurement of leaks in evacuated or pressure systems. *Consolidated Vacuum Corp.*

839. Low-Temperature Properties
Article on application of extreme low temperatures to metallurgy. Behavior of metals at low temperatures. *Arthur D. Little*

840. Lubricant
New literature on anti-seize molybdenum disulfide lubricant. *Bel-Ray*

841. Lubricant
8-page folder describes use of molybdenum disulfide lubricant in cold forming, cold heading and other applications. Case histories. *Alpha Corp.*

842. Lubricant Additive
Bulletin 424 on use of colloidal graphite dispersions in petroleum products and other fluids for industrial lubrication. *Acheson Colloids*

843. Machining Copper Alloys
12-page bulletin on machining properties, practices, feeds, speeds, tool design. *Ampco*

844. Magnesium Castings
5-page reprint tells of new developments in making magnesium castings for aircraft needs. *Dow Chemical*

845. Mechanical Tubing
Booklet on applications of mechanical tubing. Examples of shapes. *Babcock & Wilcox*

846. Melting Furnaces
New catalog on Heroult electric melting furnaces. Types, sizes, capacities, ratings. *American Bridge*

847. Melting Furnaces
8-page Bulletin 560 describes stationary and tilting types of two-chamber melting furnaces. Applications to all types of casting. *Lindberg Engineering*

848. Metal Cutting
64-page catalog No. 29 gives prices and describes complete line of rotary files, burrs, metalworking saws and other products. *Martindale Electric*

849. Metallograph
20-page bulletin E-232 on Balphot metallograph with bright field, dark field, polarized light, phase contrast. *Bausch & Lomb*

850. Metallographic Polishing
Booklet describes line of two-speed polishers. *Buehler, Ltd.*

851. Microhardness Tester
Bulletin describes the Kentron microhardness tester. *Torsion Balance Co.*

852. Moly-Sulphide Lubricant
40-page booklet on Moly-sulphide lubricant gives case histories for 154 different uses. *Climax Molybdenum*

853. Nickel Alloys
40-page book gives corrosion, physical and mechanical properties of Hastelloy alloys; 13 pages of fabrication data. *Haynes Stellite*

854. Nickel Alloys
38-page handbook on wire, rod, strip of Monel, Inconel, nickel and nickel clad copper. *Alloy Metal Wire Co.*

855. Nickel Tubing
Memorandum No. 19 on alloys from which tubing is made, sizes, properties, selection, uses. *Superior Tube*

856. Nitriding Furnace
Bulletin 646R on carburizing and nitriding furnace giving atmosphere circulation to 1850° F. *Hevi Duty*

857. Nondestructive Testing
8-page bulletin on equipment for nondestructive testing of bars, rods, tubing. *Magnetic Analysis*

858. Nonferrous Melting
Bulletin 26-A on high-frequency furnaces for melting copper, silver, gold, platinum, aluminum and magnesium. *Ajax Electrothermic*

859. Nonferrous Tubing
Bulletin on seamless, brazed and lockseam tubing in brass and copper. *H & H Tube and Mfg.*

860. Nonflammable Rust Preventive
Bulletin rust preventive compound which is water soluble, nontoxic and nonflammable. *Production Specialties*

861. Oil Quenching
8-page brochure tells in detail how carbon steel often can replace alloy steel when additive is used in the quenching oil. *Aldridge Industrial Oils*

862. Parting Compound
Bulletin 427 on how to use colloidal graphite as a parting compound. *Acheson Colloids*

863. Periodic Chart
Periodic chart of the elements, green and black, 11 by 14 in., official 1952 data. *General Electric*

864. Pickling Baskets
Data on baskets for degreasing, pickling, anodizing and plating. *Jelliff*

865. Pickling Baskets
12-page bulletin on mechanical picklers, crates, baskets, chain and accessories. *Youngstown Welding & Eng'g*

866. Pickling Compound
Folder on "Rodine" tells of its use in pickling solutions to prevent embrittlement of steel. *American Chemical Paint*

867. Piercing
Slide calculator for determining the required pressure (in tons) for piercing a given size hole in any thickness and type of metal. *Ward Machinery*

868. Plating
8-page booklet on plating rack designed to make spline section or body of rack a permanent tool. *National Rack*

869. Plating Racks
24-page catalog on racking methods and tip constructions for plating and finishing. *NARACO*

(Continued on page 32A)

What do you want in the welded stainless tubing you use?

Perhaps your biggest headache is corrosion. Maybe it's oxidation, or contamination, workability, or some combination of these. Whatever it is, the solution lies in getting the *right* welded stainless tubing for your particular operation.

With B&W welded stainless tubing you can be sure you are getting not only the right grade of stainless steel but also tubing with the properties you desire for easy fabrication and long service life.

Put your stainless tubing problems up to Mr. Tubes, your link to B&W, who represents the B&W Headquarters Technical Staff, Regional Sales Offices, and a cross-country network of experienced tubing distributors. You can have confidence in his suggestions, based on broad and intimate experience with stainless applications, to help you make the right choice for your requirements.

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THE BABCOCK & WILCOX COMPANY
TUBULAR PRODUCTS DIVISION
Beaver Falls, Pa.—Seamless Tubing; Welded Stainless Steel Tubing
Alliance, Ohio—Welded Carbon Steel Tubing

TA-4033 (SWP)

908. Sodium
24-page book on handling sodium in the laboratory and plant. Application to descaling. *Ethyl Corp.*

909. Sonic Thickness Tester
Measurement of wall thickness from one side by sonic method. *Branson*

910. Spark Testing
20-page spark test guide features spark diagrams of 13 standard tool and die steels. *Carpenter Steel*

911. Springs
"Metal Minutes" tells how leaf springs are made at Stanley Spring Works. *Sunbeam*

912. Stainless Fastenings
20-page catalog of stainless steel cap screws, nuts, washers, machine screws, sheet metal screws, set screws, pipe fittings and specialties. *Star Stainless Screw*

913. Stainless Steel
Bulletin gives examples of five types of stainless steel castings. *Sivyer*

914. Stainless Steel
Slide chart. Set top at a certain fabricating operation, bottom shows rating of each standard grade. On reverse side, heat treating and corrosion data are given. *Carpenter Steel*

915. Stainless Steel
Weekly stock lists for stainless plate give size, gage and type of stainless. *G. O. Carlson*

916. Stainless Steel
Selector gives machinability, physical and mechanical properties, corrosion resistance of various grades of stainless steel. *Crucible Steel*

917. Steel Tubing
48-page Handbook F-3 on fabricating and forging steel tubing. Bending, shaping, cutting and joining operations described. *Ohio Seamless Tube*

918. Stretchforming
Bulletin on how a structural member was formed on a contour former. *Cyril Bath*

919. Subzero Freezer
Data on chest for use down to -95° F. for production use and testing. *Revco*

920. Subzero Treatment
12-page bulletin on subzero treatment of tool steel and increase in tool life resulting. *Cincinnati Sub-Zero Products*

921. Super High Speed Steel
Folder on molybdenum, 8% cobalt high speed steel for use at speeds 20 to 25% greater than with ordinary high speed steel. Heat treatments. *Firth Sterling*

922. Temperature Recording
48-page bulletin T840 on series of recording thermometers for temperatures between -125 and 1000° F. *Bristol*

923. Testing Instruments
16-page bulletin on portable recorders, voltmeters and ammeters, surface roughness scales and other electric testers. *General Electric*

924. Textured Metal
16-page booklet on advantages and applications of textured metal. *Rigidized Metals*

925. Thermocouple Data
42-page Bulletin TC-9 on thermocouples, radiation detectors, resistance bulbs, accessories. *Wheelco*

926. Thermocouple Elements
Folder on precious metal, chromel and alumel thermoelements, porcelain and metal protection tubes. *Chas. Engelhard*

927. Thermocouples
36-page Bulletin 235-4 describes various types of thermocouples, extension wire and other accessories. *Foxboro*

928. Tool Steel Color Guide
Color guide to estimate temperatures has heat colors on one side and temper colors on the other. *Bethlehem Steel*

929. Tool Steel Heat Treat
Bulletin 1147EE on electric furnace for heat treatment of high speed tool steel. *Hevi Duty*

930. Tool Steel Selector
Twist the dial of the 9-in. circular selector and read off the tool steel for your application. *Crucible Steel*

931. Tool Steels
12-page booklet on carbon-vanadium tool steels. Compositions, microstructures, heat treatment. *Vanadium-Alloys Steel*

932. Tubing
36-page Catalog No. 30 on small tubing of carbon and alloy steel. Materials, specialties, methods of fabrication. *Superior Tube*

933. Ultrasonic Testing
Bulletin on testing equipment for measuring thickness, lack of bond, laminar-type defects. *Magnaflux*

934. Universal Tester
Bulletin on machine for tension, compression and transverse tests. *Riehle*

935. Vacuum Metallizing
16-page booklet on properties of metallized coatings, the process, and advantages of metallizing. *F. J. Stokes Machine*

936. Welding
Bulletin 2100 on air-operated bench welder for spot welding. *Universal Welder*

937. Welding Electrodes
New 24-page booklet on welding electrodes for stainless steels. Metallurgy of stainless steels, composition and uses of different electrode grades. *A. O. Smith*

938. Welding Equipment
Catalog on Cadweld process and arc-welding accessories. *Erico Products*

939. Welding Magnesium
Various welding processes for magnesium, stress relief and recommended procedures. *Brooks & Perkins*

940. Welding Magnesium
Article on inert-gas-shielded metal-arc welding of magnesium includes numerous illustrations and tables of data. *Dow Chemical*

941. Welding Rods
6-page bulletin on bronze welding rods. Table gives ASTM, AWS and Government specifications. *Titan Metal*

942. Welding Stainless
54-page manual on welding processes for stainless with recommendations and settings for arc, spot and pulsation welding. Soldering and brazing. *Republic Steel*

943. Wire Baskets
84-page book on fabricated baskets for dipping and heat treating. *Cambridge Wire Cloth*

944. X-Ray Diffraction
Bulletin 8A-3505 on film or direct recording X-ray diffraction apparatus. *X-Ray Div., General Electric*

945. Zirconium
26-page booklet gives physical, mechanical and chemical properties, present and potential uses, supply and prices of zirconium. *Zirconium Metals*

August, 1954

653	678	703	728	753	778	803	828	853	878	903	928
654	679	704	729	754	779	804	829	854	879	904	929
655	680	705	730	755	780	805	830	855	880	905	930
656	681	706	731	756	781	806	831	856	881	906	931
657	682	707	732	757	782	807	832	857	882	907	932
658	683	708	733	758	783	808	833	858	883	908	933
659	684	709	734	759	784	809	834	859	884	909	934
660	685	710	735	760	785	810	835	860	885	910	935
661	686	711	736	761	786	811	836	861	886	911	936
662	687	712	737	762	787	812	837	862	887	912	937
663	688	713	738	763	788	813	838	863	888	913	938
664	689	714	739	764	789	814	839	864	889	914	939
665	690	715	740	765	790	815	840	865	890	915	940
666	691	716	741	766	791	816	841	866	891	916	941
667	692	717	742	767	792	817	842	867	892	917	942
668	693	718	743	768	793	818	843	868	893	918	943
669	694	719	744	769	794	819	844	869	894	919	944
670	695	720	745	770	795	820	845	870	895	920	945
671	696	721	746	771	796	821	846	871	896	921	
672	697	722	747	772	797	822	847	872	897	922	
673	698	723	748	773	798	823	848	873	898	923	
674	699	724	749	774	799	824	849	874	899	924	
675	700	725	750	775	800	825	850	875	900	925	
676	701	726	751	776	801	826	851	876	901	926	
677	702	727	752	777	802	827	852	877	902	927	

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Company

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City and State

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(Continued from page 31)

870. Platinum Cladding
Bulletin on how it is made, thickness of cladding, testing, applications. *Baker & Co.*

871. Powder Metal Parts
168-page catalog, B-44, on bronze and ferrous alloys. Engineering data and information including design data, load capacities, specific properties, assembly procedure. *Amplex Div.*

872. Powdered Metal Parts
Bulletin points out powdered metal parts which can be molded or must be machined. *Chicago Powdered Metal Products*

873. Powder Metallurgy
Information on sponge iron powder. *Ekstrand & Tholand*

874. Precision Casting
20-page booklet on ethyl silicate as a refractory mold binder for precision investment casting. *Carbide and Carbon Chemicals Co.*

875. Precision Casting
8-page bulletin on investment castings of various ferrous and nonferrous alloys. *Engineered Precision Casting*

876. Precision Castings
20-page book on alloys used, specification ranges, advantages and castings made by precision casting. *Haynes Stellite*

877. Presses
Catalog of power press brakes for sheet metal and plate. Applications possible with various dies. Design and manufacture. *Airtherm Mfg. Co.*

878. Presses
8-page booklet on hand and power operated benders, brakes, notchers, punch presses. *O'Neil-Irwin Mfg.*

879. Pressure Vacuum Gages
32-page Catalog 7001 on gages for vacuums to 10 "mm. Hg and pressures to 150,000 psi. *Minneapolis-Honeywell*

880. Protective Coatings
Selection charts of chemicals for paint bonding on steel, zinc and aluminum, rust proofing and lubrication for cold forming. *American Chemical Paint*

881. Protective Coatings
Comparison chart of twelve protective coatings gives resistance of each to abrasion, acids, chemicals, corrosion, gasoline, oils and greases, salt water, fresh cold water and hot water, dry temperatures and fire. *Industrial Metal Protectives*

882. Pure Metals
Data sheets on vacuum melted cobalt, copper, iron and nickel. *Vacuum Metals*

883. Pyrometer Supplies
Buyers' Guide for pyrometer supplies No. 100-5. *Minneapolis-Honeywell*

884. Pyrometers
Folder on pyrometers for high and low temperature indications. *Claud S. Gordon*

885. Pyrometers
New bulletin, "Temperature Indications," on basic facts about pyrometry and line of pyrometers. *Illinois Testing Labs.*

886. Quenching
"Handbook on Quenching" gives complete information. *E. F. Houghton*

887. Quenching
Bulletin 120 on use of heat exchangers to provide heat control in quenching bath. *Niagara Blower*

888. Quenching Oil
8-page booklet on applications and cost reductions in oil-quenching installations. *Sun Oil*

889. Radiation Protection
12-page booklet on films for determining amount of radiation. Used in research laboratories, nondestructive testing laboratories. *Du Pont*

890. Refractories
12-page bulletin on six types of insulating brick, how to insulate, thermal data. *Harbison-Walker Refractories*

891. Refractories
32-page booklet on plastic refractory and its use in soaking pits, car bottom furnaces, blast furnaces, openhearths. *Ramtite*

892. Refractories
Booklet on recommendations for high-temperature insulation in openhearth furnaces. *Illinois Clay Products Co.*

893. Refractories
12-page reprint on Abrasion-Resistant Refractory Materials as Applied to Blast Furnace Operations. *Refractories Div., Carborundum*

894. Refractories
12-page brochure on products for casting special refractory shapes and for gunning and troweling applications, for services to 3000° F. *Johns-Manville*

895. Refractory
Reprint on Current Refractory Practice as Applied in Copper Smelting. *Harbison-Walker Refractories*

896. Resistance Testing
Bulletin 100 on production tester for measuring electrical resistance. *Rubicon*

897. Resistance Welding
24-page catalog on equipment for resistance welding includes reference tables and property and application charts. *Ampco*

898. Rhodium Plating
Data on properties, thicknesses required, costs, operation, applications. *Technic*

899. Rust Prevention
Booklet on how water-displacing oil protects against rust during production and in storage. *Oakite*

900. Salt Bath Furnaces
Data on salt bath furnaces for batch and conveyorized work. *Upton*

901. Salt Baths
72-page catalog, 116 B, on operating principles and use of salt baths for 26 heat treating processes. *Ajax Electric*

902. Salt Baths
28-page book deals with heat treatment, carburizing, bath maintenance, safety precautions. *American Cyanamid*

903. Sand Control
32-page book on defects and troubles in foundry and how to remedy through sand control. *Claud S. Gordon Co.*

904. Saws
Catalog C-53 describes 35 models of metal-cutting saws. *Armstrong-Blum*

905. Selective Carburizer
Bulletin on "No-Carb" for selective carburizing and prevention of decarburizing on high alloy steels during heating for hardening. *Park Chemical*

906. Shot Peening
16-page booklet on selection and use of shot and grit for peening. *Cleveland Metal Abrasive*

907. Shotblasting
16-page "Primer on the Use of Shot and Grit." Problems of blast cleaning operations. *Hickman, Williams*

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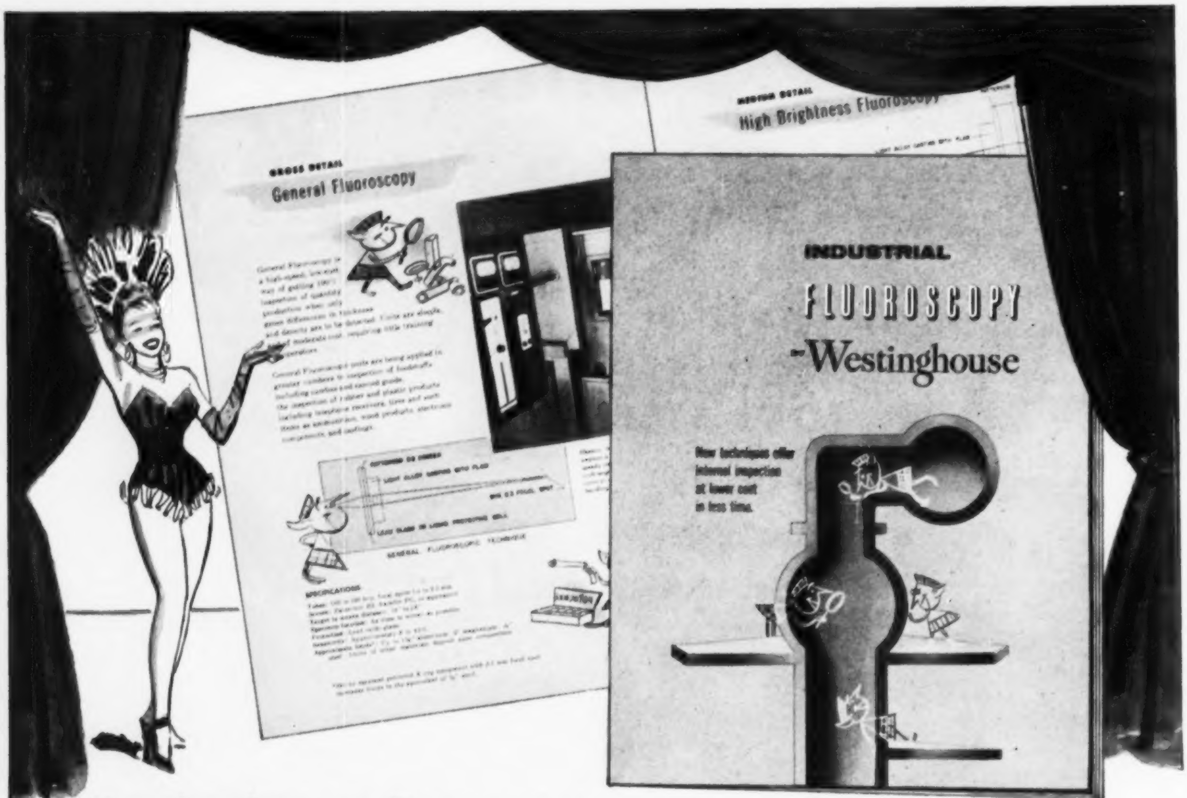

Westinghouse Presents:

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Cheaper, Faster Internal Inspection

Westinghouse has lifted the curtain on its newest aid to industry: INDUSTRIAL FLUOROSCOPY, a twelve-page color booklet that explains and illustrates the uses of fluoroscopy for non-destructive internal inspection.

INDUSTRIAL FLUOROSCOPY carries full information on the three methods of fluoroscopic testing: General Fluoroscopy for gross detail, High Brightness Fluoroscopy for medium detail and High Definition Fluoroscopy for fine detail. In addition, INDUSTRIAL FLUOROSCOPY explains and illustrates the Fluorex Image Amplifier — a useful accessory that may be used with any of the above methods to intensify image brightness more than 200 times.

If you are looking for a practical, economical way to solve your internal testing problems, send for this descriptive booklet today. Fill in and return the coupon below, or call your local Westinghouse X-Ray representative.

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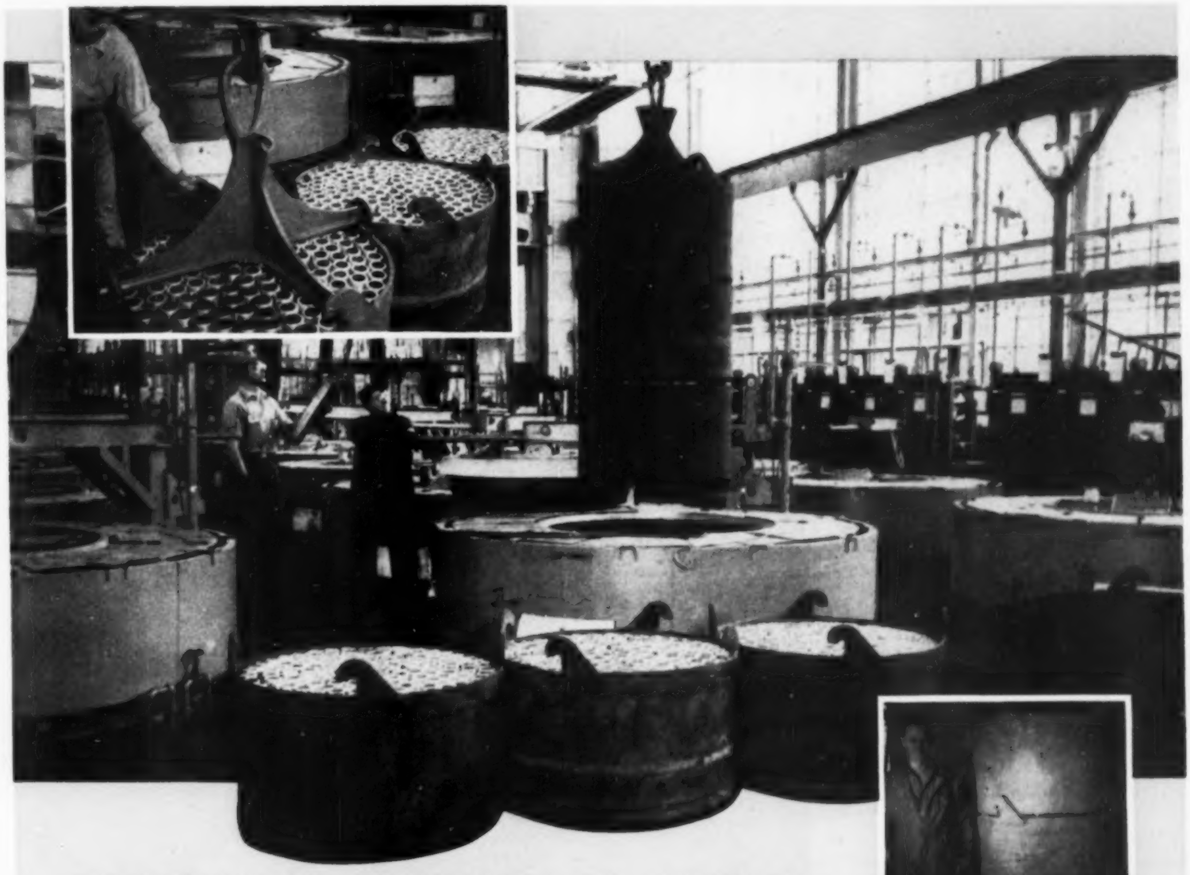

CATERPILLAR TRACTOR CO. MOVES 4½ TONS IN A SINGLE LOAD!

"WHAT'S so unusual about moving four and a half tons?" Nothing . . . except at CATERPILLAR TRACTOR CO., Peoria, Illinois, where track bushings are carburized at 1700° F. in a pit type furnace . . . 3½ net tons at a time.

This is accomplished with the use of alloy baskets designed by ACCOLOY ENGINEERS in collaboration with Engineers of CATERPILLAR TRACTOR CO. and produced in the plant of ALLOY ENGINEERING & CASTING CO., Champaign, Illinois.

Each basket shown above is 37" diameter by 22" deep and when fully loaded contains over one ton of track bushings. With a complete load of three baskets, the gross weight is in excess of four and a half tons.

Outstanding design features of these baskets are (1) uniform metal sections throughout (2) ration of pay-load to alloy weight is over 3.3 to 1. (3) simplified interlocking of baskets results in easy loading and unloading (4) basket grids designed to give uniform flow of carburizing gas through dense load (5) grids designed for reversibility. Original baskets are still in use after 2½ years. Here again is a notable example of a tough job that was effectively solved by engineering skill and co-operative effort between the supplier and user.

We welcome the opportunity to work with you on your High Temperature problems. Consult your nearest ACCOLOY Engineer without obligation and discover why these quality castings are "preferred by industry."

HEAT RESISTANT CASTINGS
ACCOLOY
STAINLESS STEEL CASTINGS

ALLOY ENGINEERING & CASTING CO.

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CHAMPAIGN • ILLINOIS

ENGINEERS AND PRODUCERS OF HEAT AND CORROSION RESISTANT CASTINGS


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Choose

NORTH AMERICAN MFG. CO.

This Company, since 1917, has served industry with the right combination of scientific knowledge and engineering know-how, to produce greater savings through greater efficiency in combustion problems.

With superior manufacturing and testing facilities and responsible field engineering, NORTH AMERICAN maintains district offices in principal cities throughout the United States. These offices are manned by factory-trained full-time combustion engineers, in:

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Consult these experts for help with your fuel-burning problems. Ask them for a copy of the NORTH AMERICAN COMBUSTION HANDBOOK.


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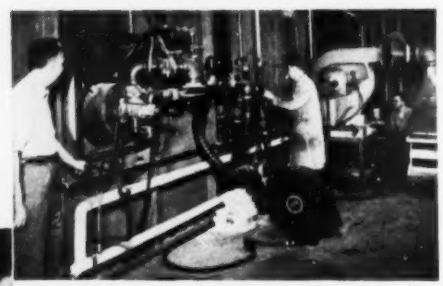
INTERIOR OF FACTORY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MANUFACTURERS OF
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Steel-Weld
FABRICATION
Use WELDED STEEL
for Greater Strength
with Less Weight!
The Crawler Side Frames illustrated above, parts of a large strip mining machine which were formerly produced in casting form, were redesigned and produced by Mahon as weldments. These and the parts and assemblies shown at the left are typical of thousands of Steel-Weld Fabricated units produced and machined by Mahon for hundreds of manufacturers of processing machinery, machine tools and other types of heavy mechanical equipment. If you require welded steel parts, assemblies, or special purpose equipment, you can turn to Mahon with complete confidence . . . highly skilled personnel are available within the Mahon organization to do the complete job from drawing board to finished machining and assembly—thoroughly experienced personnel who are backed by tools and plant facilities with capacity to produce virtually anything in welded steel construction regardless of size or weight. You will find in the Mahon organization a unique source for Steel-Weld Fabrication . . . a source where skillful designing, advanced fabricating techniques and superior craftsmanship assures you a smoother, finer appearing job embodying every advantage of Steel-Weld Fabrication. See Mahon's Insert in Sweet's Product Design File, or have a Mahon engineer call and give you complete information.
THE R. C. MAHON COMPANY
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Engineers and Fabricators of Steel in Any Form for Any Purpose
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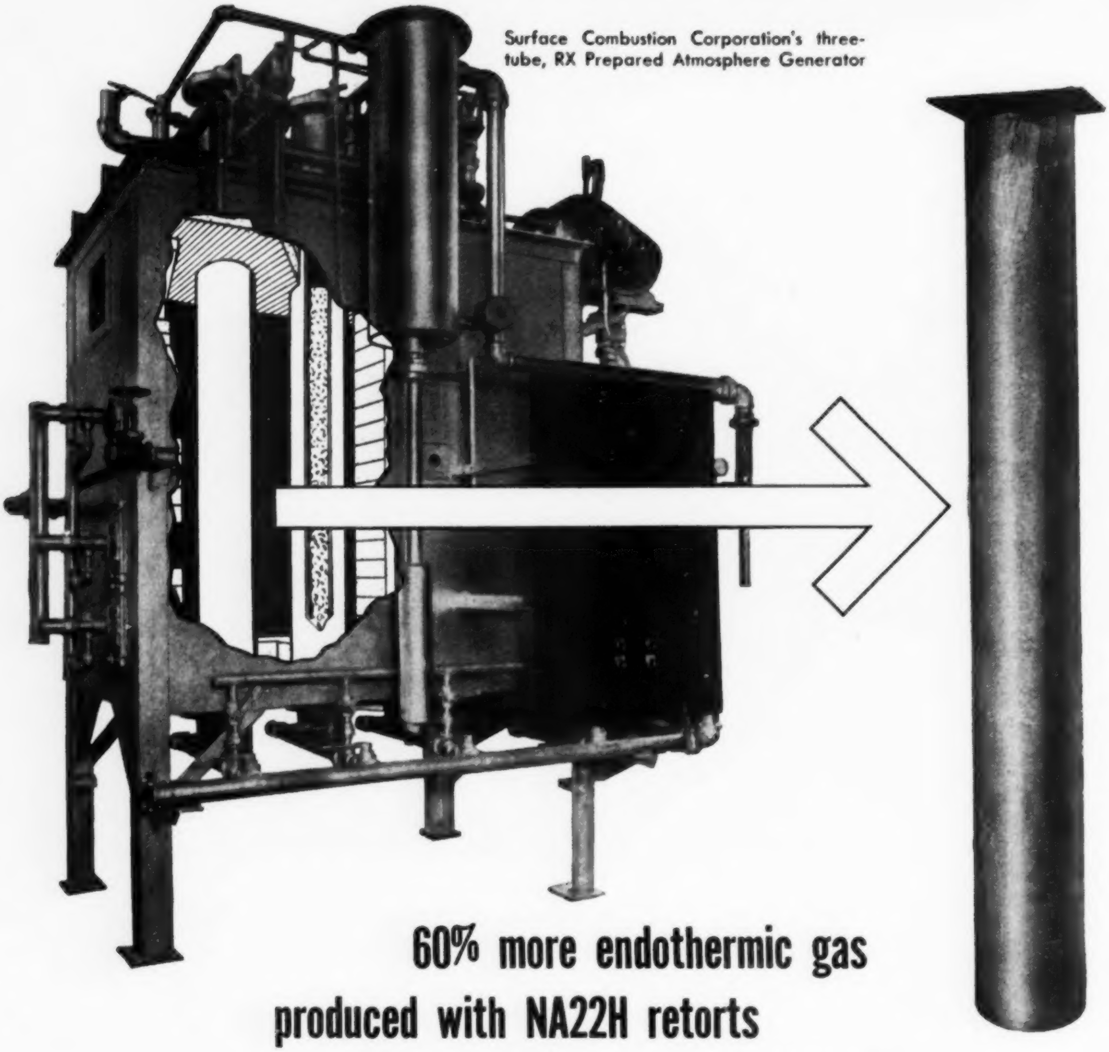
Surface Combustion Corporation's three-tube, RX Prepared Atmosphere Generator



60% more endothermic gas produced with NA22H retorts without increasing generator size

WHAT CAN THIS NEW ALLOY DO FOR YOU?

Prior to the installation of NA22H retorts, endothermic gas generators of the type shown above operated at approximately 1850F.

With generator design improvements to take advantage of the increased heat resistance of NA22H alloy retorts, these same generators now may be operated at temperatures from 2050F to 2100F . . . producing up to 60 percent more gas of greater uniformity.

The life of NA22H retorts, operating continuously at these temperatures, exceeds that of 35Ni-15Cr(HT) at 1850F.

This is just one of the many jobs that this new high temperature alloy is doing so well. What can it do for you?

•

You'll find other interesting case histories, operating data and the results of extensive tests in the new Blaw-Knox Booklet entitled, "NA22H." Write for it.

BLAW-KNOX

BLAW-KNOX COMPANY

NATIONAL ALLOY DIVISION

Pittsburgh 38, Pennsylvania

CLEANING SPECIALISTS

give you a "brighter" outlook on life.

It's amazing how pleasant the view can be after one of these steel-nerved, sure-footed, alert Cleaning Specialists have done their job.

Northwest's Metal Cleaning Specialists are "alert" to your problems when it comes to giving your products a "brighter" outlook. Day in—day out, Northwest carries on the constant search for better, lower cost, analytically-correct cleaners to give you dependable, good looking, permanent finishes.

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Northwest's production-tested chemicals and "Right-the-first-time" recommendations will save you money. Northwest Service is as close as your phone.

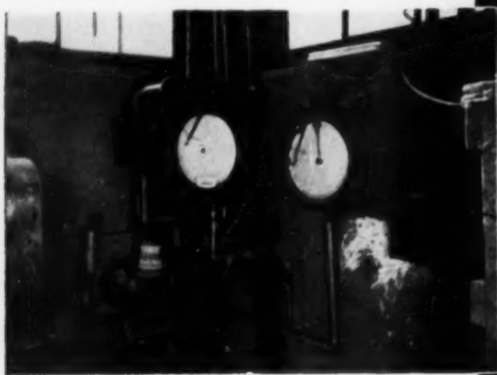
Remember —YOUR COST PER FINISHED ARTICLE IS THE TRUE COST OF YOUR CLEANER

LO-HI pH

NORTHWEST CHEMICAL CO.

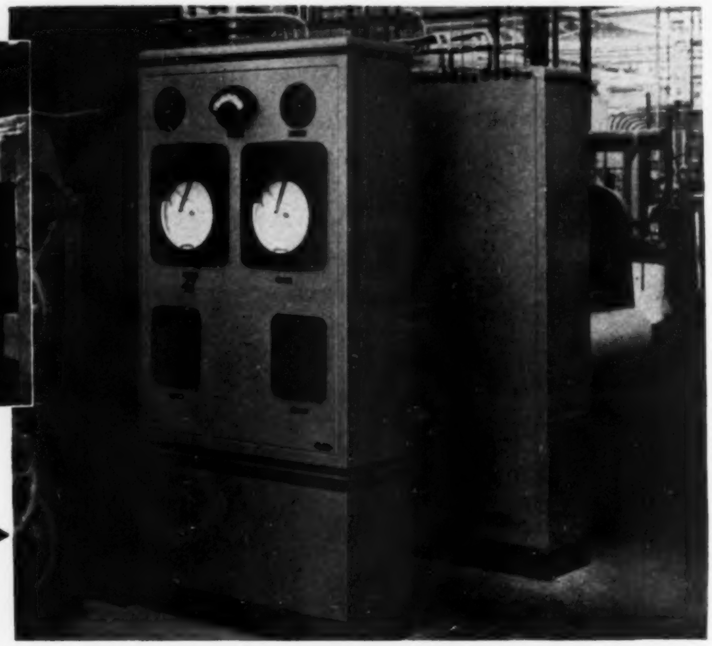
9310 ROSELAWN DETROIT 4, MICH.

pioneers in pH cleaning control *serving you since '32*



This is part of an old-fashioned installation which lacks the convenience and efficiency of modern instrumentation.

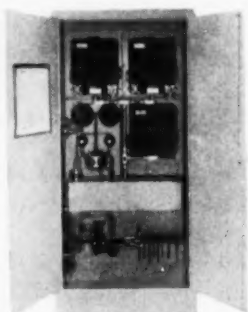
Compare this centralized Foxboro Cabinet installation of similar instrumentation, which saves time for the operator, makes his work more efficient, and gives maximum protection to the precision instruments required for his process.

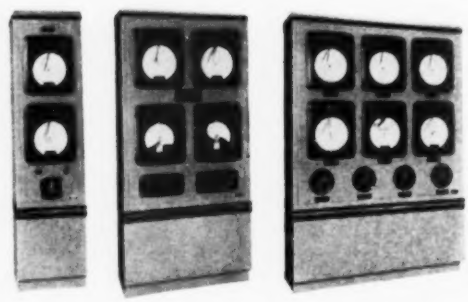


See what a difference FOXBORO cabinet-mounting can make!

These photos show at a glance how much more efficient and attractive your instrument installation can be if it's integrated and centralized in a Foxboro Cabinet. Not only are the instruments protected from dust and process "atmospheres", but they're conveniently grouped together for more efficient use and easier maintenance. Those "endless steps" of the operator are a thing of the past!

Foxboro will supply a cabinet (or cabinets) to house and protect any number of existing instruments and related devices. Or your order for new instruments can be shipped to you already mounted in cabinets, completely piped and wired, needing only simple power and process connections to be put into operation. Write for illustrated and informative Bulletin 413.





Foxboro Cabinets are available in three standard sizes for 2, 4, or 6 conventional-size instruments (or equivalent). For mounting more than 6 instruments, Foxboro Sectional Cabinets (with open ends) are used . . . bolted together to form desired length. End sections have one closed side to form dust-tight enclosure. Exclusive insert-type panel construction permits easy conversion when process changes so require.

THE FOXBORO COMPANY, 528 NEPONSET AVENUE, FOXBORO, MASS., U. S. A.

FOXBORO REG. U. S. PAT. OFF. **PROCESS CONTROL CABINETS**

FACTORIES IN THE UNITED STATES, CANADA, AND ENGLAND

each a

first quality

tool steel

designed, made and proved to deliver maximum performance value in every industrial field of application

guaranteed by deep etch, magnaflux, zyglo and supersonic testing

VANADIUM-ALLOYS STEEL COMPANY

Manufacturers of First Quality Tool and Die Steels

Latrobe, Pennsylvania

COLONIAL STEEL DIVISION • ANCHOR DRAWN STEEL CO.

In Canada: Vanadium-Alloys Steel Canada Limited, London, Ontario

High Speed Steels

Red Cut Superior†
E. V. M.
Red Cut Cobalt
Red Cut Cobalt B
Gray Cut Cobalt
Vasco M-2†
Van-Lom†
8-N-2†
Neatro†
Vasco Supreme†
Van Cut

Die Steels for Hot Work

Hotform
Choice
Marvel
Hotpress
Forge-Die
SC Special
WW Hotwork
Red Cut Superior ("J" Temper)

Die Steels for Cold Work

Non-Shrinkable
Colonial No. 6
Air Hard
Crocar†
Ohio Die†
Red Star Tungsten
Colonial No. 4

Carbon and Carbon-Vanadium Tool Steels

Colonial No.14
Colonial No. 7
Extra L
Elvandi
Red Star Tool
Red Star Vanadium

Chrome Vanadium Tool Steels

Vanadium Types D-G-H-K-N
Vanadium Type BB

Tool Steels for Special Purposes

Colhed
Par-Exc
Silman
Mosil
CM
Croman
Nikro M
Speed-Cut

Drill Rod

Red Anchor
Blue Anchor
Gold Anchor
Oil Hardening
Carbon-Vanadium
Red Star Tungsten
Special Analyses

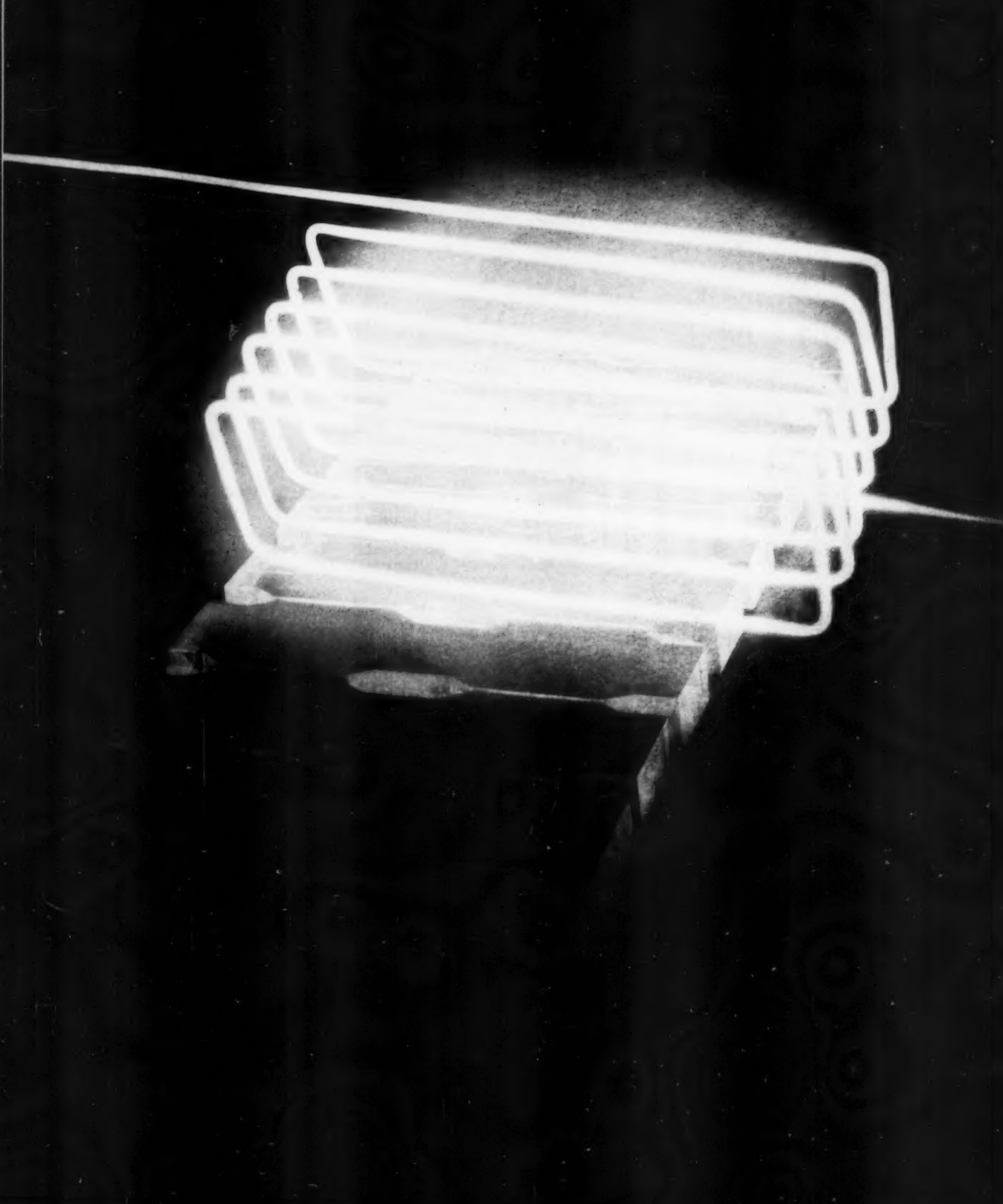
Cold Drawn Shapes

Special Steels

Our Tool Steels are produced in every form, including hammer-finished bars and blocks, disc and ring forgings, standard and special hot rolled shapes and cold drawn shapes, plates, sheets, rings punched from plate, and tool bits.

†These grades also available in Free Machining (FM) Type.

ANOTHER WESTINGHOUSE FIRST IN INDUCTION HEATING FOR FORGING . .



an ACCO product

Wilson "Rockwell"* Hardness Testers

Eliminates Operations... Increases Tests per Hour

SET-O-MATIC*

DIAL GAUGE

• Eliminates human error. Operator merely applies minor load and taps depressor bar. No setting of dial to zero.

OTHER FEATURES

- **Major load applied under dash pot control**
- **Major load removed by motor**
- **Illuminated Dial Gauge**
- **Illuminated Penetrator**

• All you have to do with the Model Y WILSON "ROCKWELL" Motorized Hardness Tester is apply the minor load and tap the major load depressor bar. The machine does everything else automatically. The cycle of Major Load operation may be less than 2 seconds.

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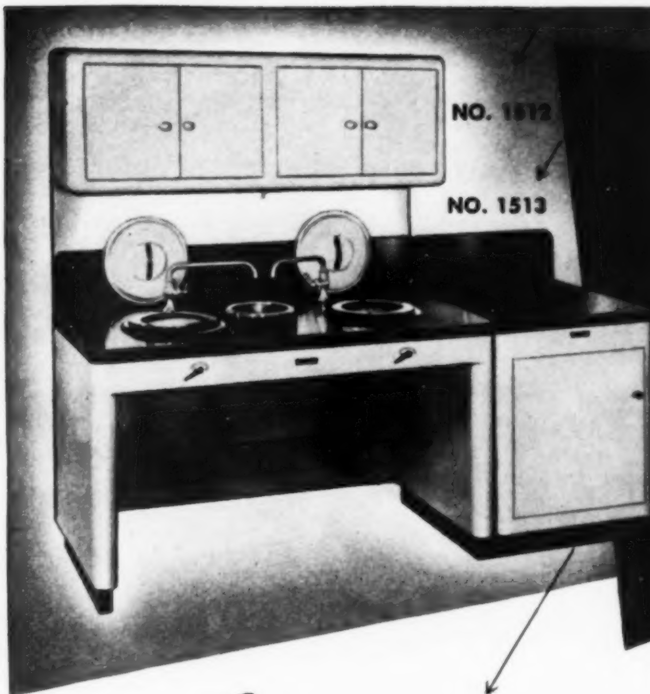

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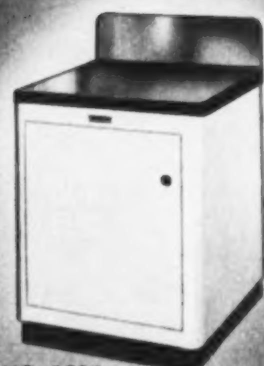

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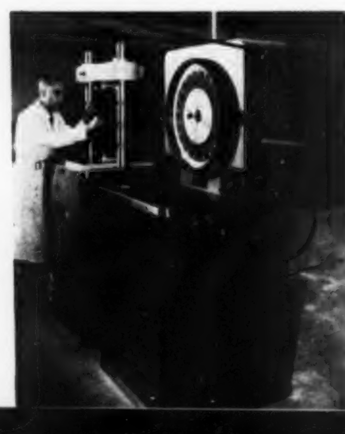

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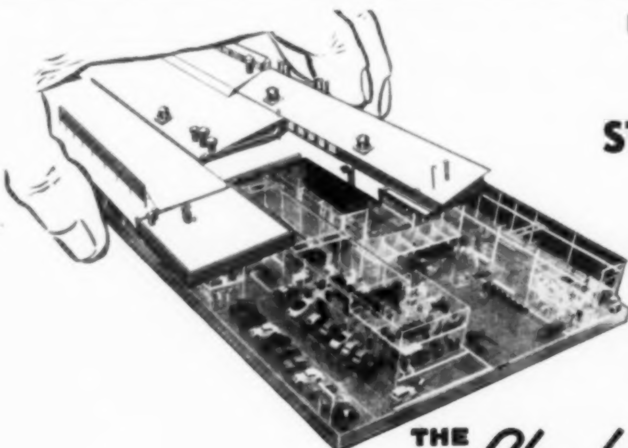

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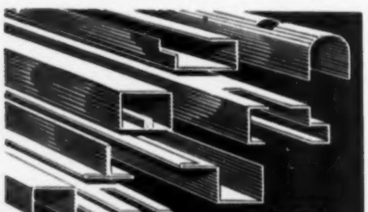

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The high stresses in propeller blades and hubs naturally require extremely high quality steels. Accordingly, the U.S. Army and U.S. Navy have set up rigid quality specifications requiring that every heavily stressed part must be magnafluxed several times during its production.

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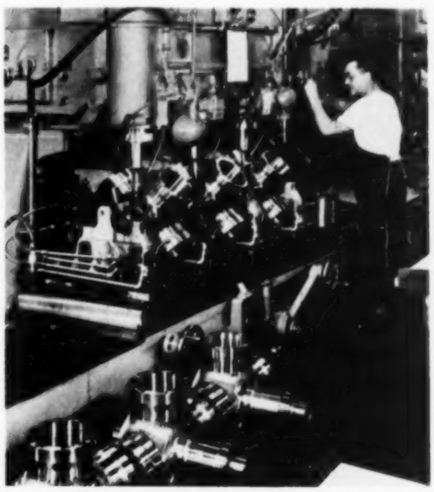
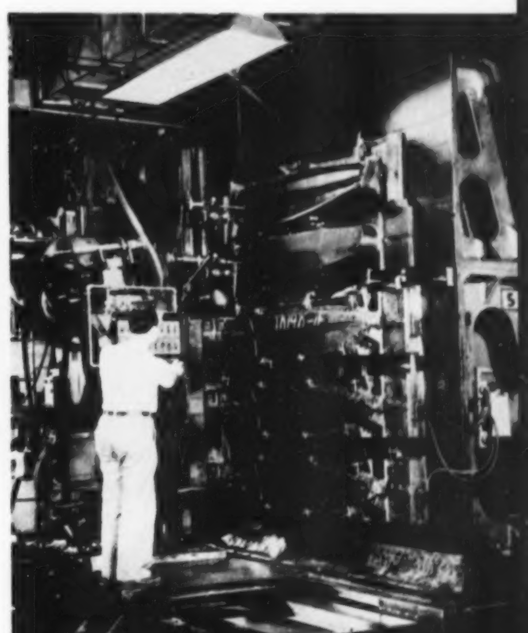


THESE HIGH QUALITY aircraft propeller hubs are forged and machined from semifinished CARILLOY 4340. They meet extremely tough magnaflux requirements.



AFTER FORGING AND MILLING, 750-lb. thrust sections are hogged out on this Kellering machine. Finished sections weigh about 155 lbs. USS CARILLOY steel maintains a No. 1 quality position on these heavy-duty parts.

FOR BIG PROPELLERS, 2 forged sections **(a)** are welded together to form one blade thrust member. Pieces are then ground and magnafluxed, Kellered, ground, and magnafluxed again **(b)**. Mill camber sheets **(c)** then are copper brazed to the thrust members. Entire unit is heat treated and polished before final magnaflux test and cadmium plating. Rigorous magnaflux testing assures that every finished blade **(d)** can withstand the tremendous stresses encountered on the latest high-speed planes.

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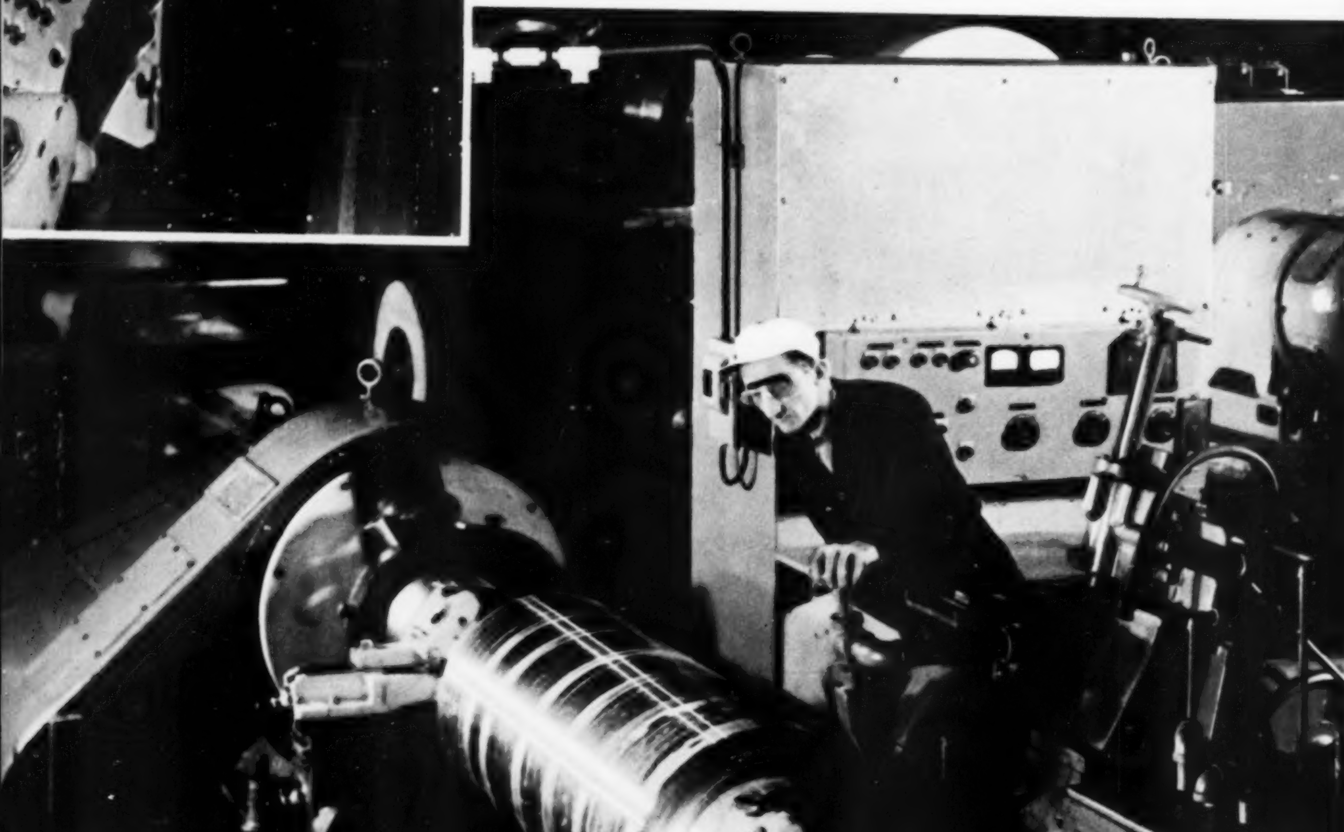

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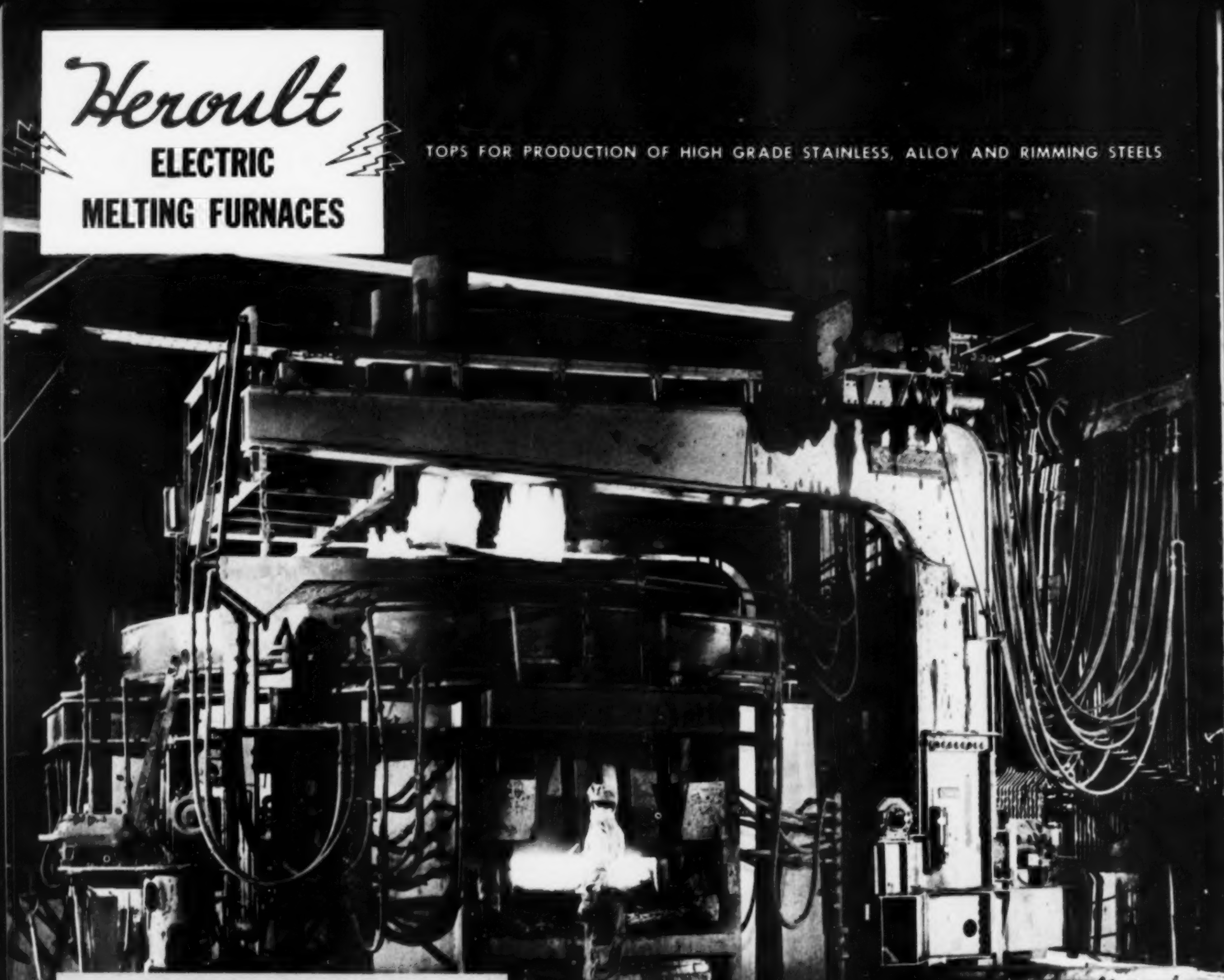

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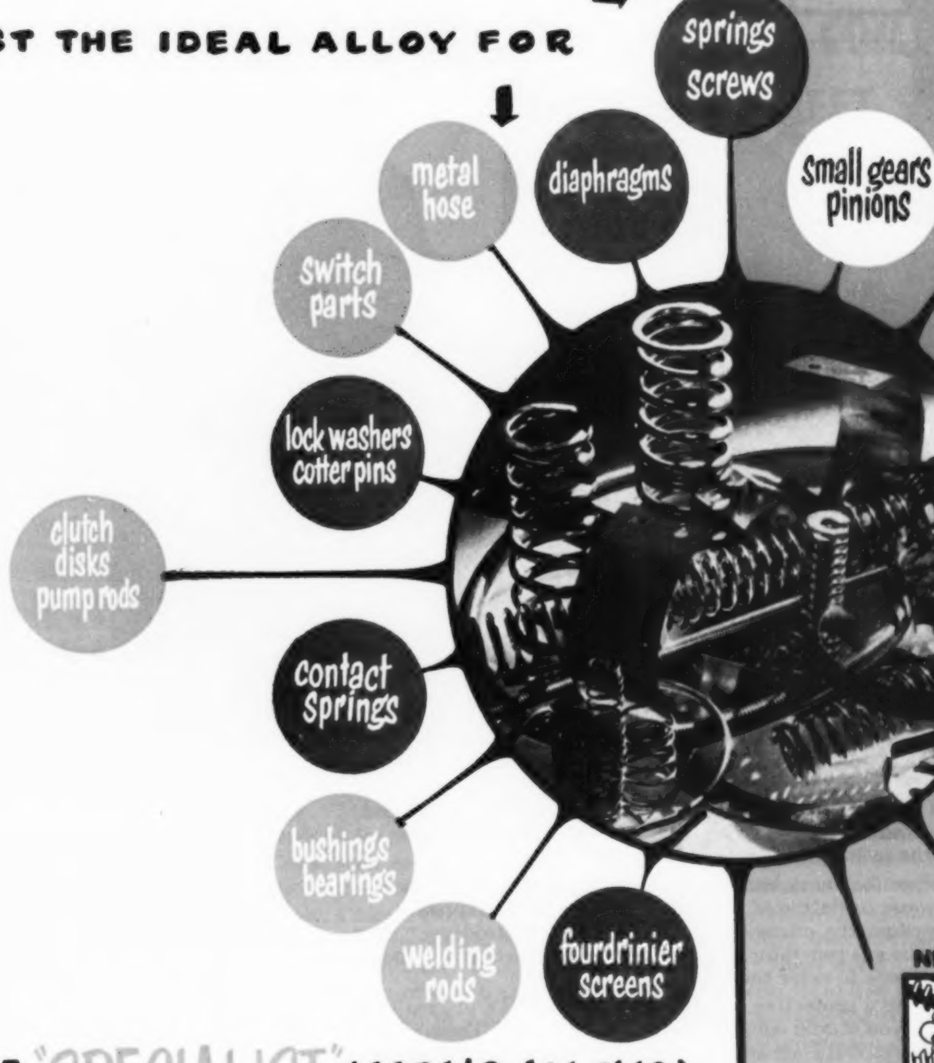

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"I like 506's blue base, too, because it helps when reading film. Since I do most of the interpreting myself, I can appreciate the lessening in eyestrain and heartily agree that the blue base makes flaws more discernible."

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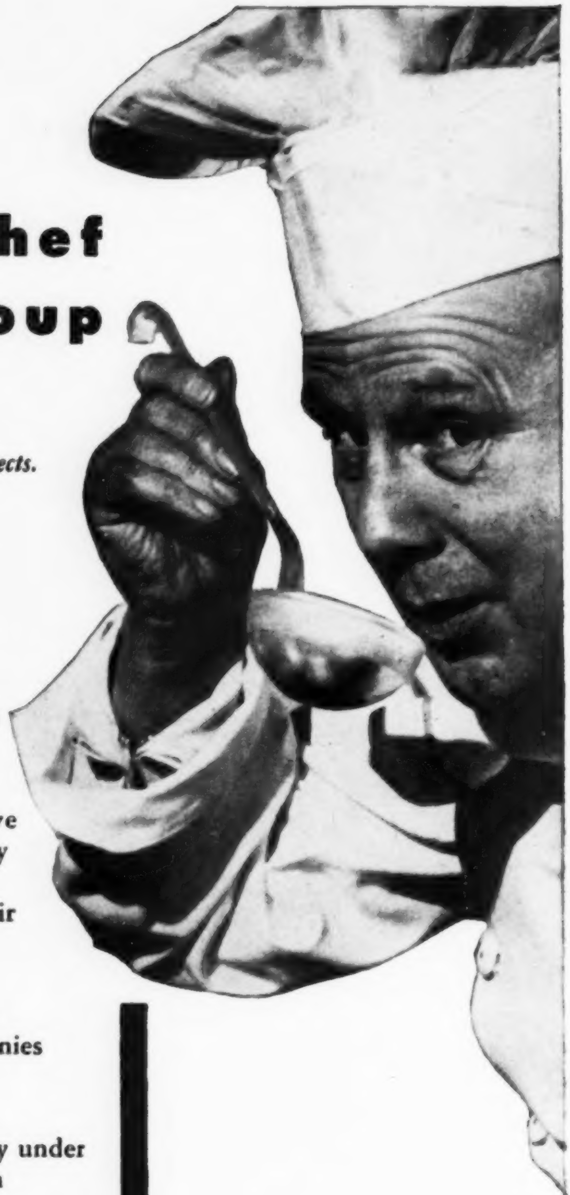

Ever watch a good chef at work?

He doesn't trust to luck — he tastes — samples — *inspects.* He practices his own kind of process control — looking for imperfections while there's still time to correct them, without throwing away his finished product or his time!

There's an example here for many manufacturers. The *earlier* in your production that you can spot defects in parts or materials, the less it costs to salvage or scrap them — and to correct the process that causes the defects.

You might call this kind of process control "correctioneering." Usually it includes nondestructive testing methods by Magnaflux'*. For inspection by Magnaflux lets you know usefulness in advance — finds defects when and as they occur — prevents their recurrence — and avoids waste of processing time, labor and money.

This money-saving use of Magnaflux' methods is practiced by hundreds of efficiently operated companies — making everything from kitchen sinks to parts for guided missiles.

The cost?—Far less than the savings; total is usually under a penny or two per part inspected — with inspection at production speeds, when required.

Why not find out now where "correctioneering" by Magnaflux' methods can save you money — *and how much.* Ask to have a Magnaflux engineer give you the facts.

**Magnaflux is a U. S. registered trade mark of Magnaflux Corporation.*

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Tool Steel Topics

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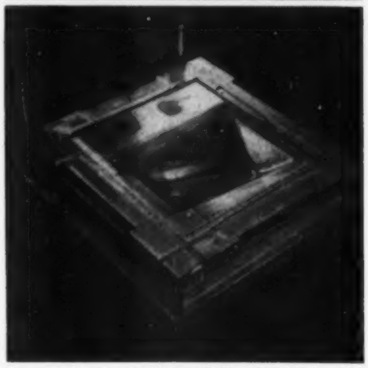


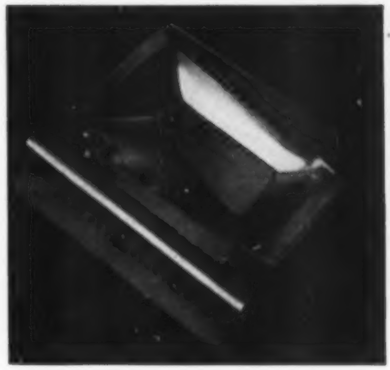
Top and bottom sections of drawing die, made of BTR, which was used in manufacture of the water-fountain top illustrated at right.

The oblong section shown at right, a stainless-steel top for an electric water fountain, is one of a vast array of interesting specialty products being turned out by L. F. Grammes & Sons, Inc., Allentown, Pa.

To manufacture this part economically, engineers at the Grammes plant required a die having good wear-resistance, low distortion and good resistance to shock. What's more, they also wanted a tool steel that was both easy to machine and heat-treat.

BTR (Bethlehem Tool Room) was selected for the drawing die, which was hardened to Rockwell C-60 before being put to work in a 200-ton press. It's been giving a good account of itself, too. At last report, some 25,000 water-fountain tops had been produced, without any sign of die-wear.

BTR is a tough steel, with outstanding resistance to abrasion. You'll find it ideal in every way for many intricate tool-and-die applications.



BTR is our general-purpose type of oil-hardening tool steel, and has this typical analysis:

Carbon	0.90	Chromium	0.50
Manganese	1.20	Vanadium	0.20
	Tungsten 0.50		

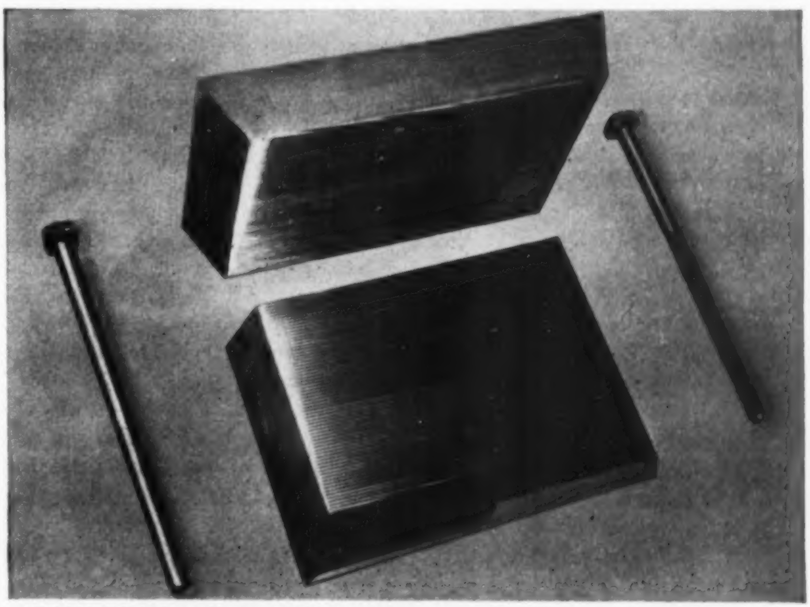
BETHLEHEM TOOL STEEL ENGINEER SAYS:

Don't Overlook the Interrupted Quench

One hears such a lot these days about isothermal annealing, martempering, automatic heat-treatment furnaces and a host of other modern processes that it is easy to overlook some of the old-time procedures which are still useful. For example, the interrupted quench.

An interrupted quench involves quenching a tool in water, then removing it from the water before the hardening transformation has started, and finishing the quench in oil. The tools should be removed from the oil while still warm, and should be tempered immediately. On water-hardening steels, an interrupted quench permits hardening of intricate sections which might crack if water-quenched all the way.

With oil-hardening steels, the interrupted quench permits hardening of sections which are too large to harden properly if oil-quenched all the way. At the same time this practice avoids the cracking which might possibly occur if a straight water quench were used.



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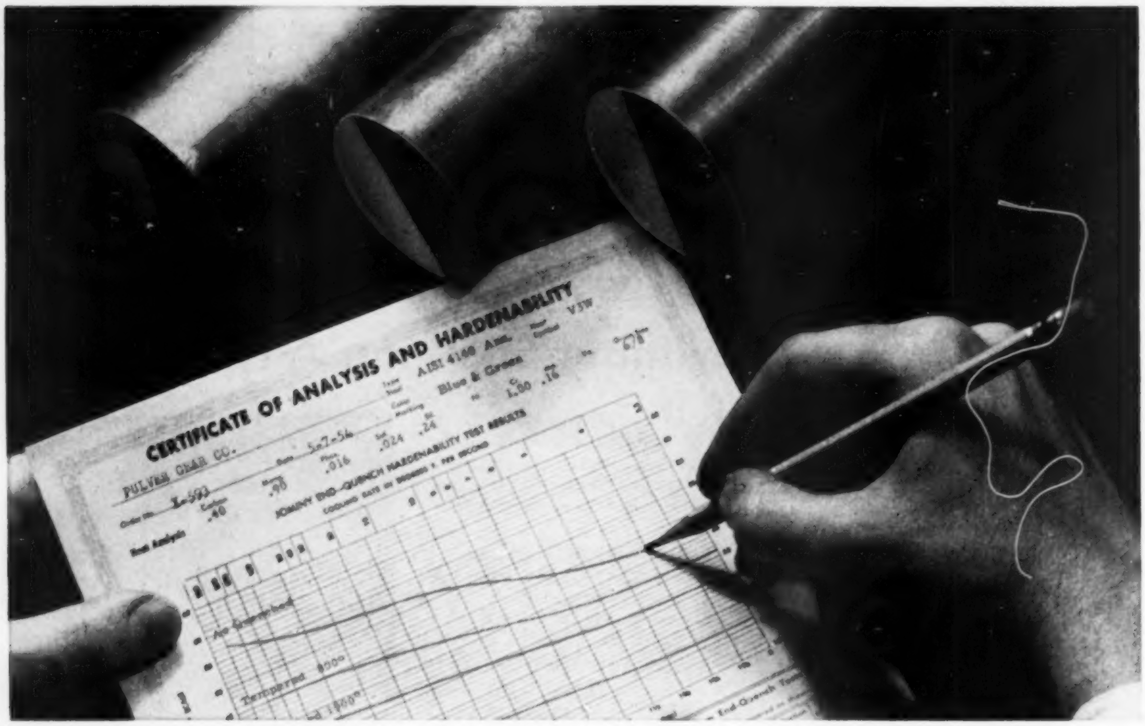

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Metal Progress

Volume 66, No. 2 August 1, 1954

In-Process Machining of Large Aluminum Forgings

By ALFRED H. PETERSEN*

Rough machining of large aircraft forgings after blocking and before finish forging or contouring and heat treatment is recommended to minimize residual stress, improve fatigue life, reduce size tolerances and economize on finish machining.

T THE very outset it might be desirable to define the phrase "in-process machining" used in the title. It refers to machining on rough forgings – or at least on forgings before they have received their final shape by coining, restriking or contouring. The following discussion will support the proposition that dimensional tolerances of large forgings will be improved if a minimum of machining be done after heat treatment, and as much machining as possible be done before the forging program is completed.

The current trend in basic structures for high-speed aircraft is toward single-unit components of high-strength nonferrous alloys. The reasons are, first, to gain a more efficient structure having a minimum of attachments with the mass of the structure and so disposed that it can carry the required loads with the least possible weight. Second, since the required loads have increased the size and weight of airplanes, the fabrication and assembly of many small units into a single structure has increased alarmingly in cost and production time. A third reason is found in the fact that as cross-sectional areas of airfoils become thinner, the space required for the large spars and ribs of conventional torquebox structures is no longer available; wide profile extrusions, machined plates and complex forgings have therefore become attractive to the designer because they simplify problems in mass and load distribution. Lastly, the present trend toward lifting surfaces of variable incidence invites the use of forged and extruded members whose configuration can be planned and arranged in the most efficient manner.

*Research Group Engineer, Lockheed Aircraft Corp., Burbank, Calif. The writer is indebted to Frank Klima of Bessemer Forge Co. and to G. Moudry and H. F. James of Harvey Aluminum Co. for timely advice during preparation of this paper.

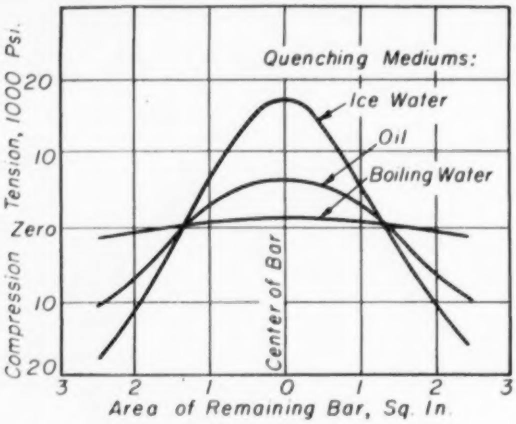


Fig. 1 – Longitudinal Residual Stresses in 2½-In. Round of Aluminum Alloy 122 Depend on Severity of Quench. Stresses determined by measuring length of the bar after thin layers are machined successively from the cylinder. (Kempf, Hopkins and Ivanso, Transactions, *American Institute of Mining and Metallurgical Engineers, 1934, p. 560)*

Adoption of such heavy, single-unit structural components has created problems which are concerning many of the best minds in the business. Paramount are the matter of dimensional stability during machining and the metallurgical properties of the material. It is believed in many quarters that in-process machining will alleviate some of these problems and at the same time improve the economy of the forging operation.

Dimensional Stability

The problem of dimensional stability during machining is constantly being encountered in the tooling and manufacturing departments. Heavy aluminum plate, extrusions, and forgings are especially susceptible to warpage and distortion during machining. Special techniques – such as heating and cooling of parts and tools, time delays between machining operations, and shot-peening of surfaces – have been employed with varying degress of success.

Some actual examples of the difficulty experienced by the aircraft industry will illustrate the condition and the extensive steps sometimes necessary to correct it.

1. A 10-lb. forging of 75 S-T 6 aluminum alloy could not be held to the required tolerance during machining except by "staging cuts" based on knowledge of which way the forging relaxed after each cut, and allowing the forging to rest a number of days after each cut.

2. A 75S-T6 forging containing bosses 5 in. in diameter and 2½ in.-thick was bored to 3-in. diameter of close dimensional tolerance. During the finish cut, after initial boring operations, circumferential cracks appeared near the center of the bores. It was necessary to allow a full day to elapse after drilling before rough boring, and another full day's time between the rough and finish boring operations.

3. Large wing panels made from 75 S-T 6 plate stock warped in unpredictable directions during machining. In order to straighten the wings it was necessary to apply loads equal to 20% of the compressive yield stress for the material. Shot-peening then reinstated the beneficial compressive stresses after cold bumping. It was essential to have the mill identify the edges of plate first entering the hot mill, the roller leveler and the quench. In this manner, the degree and direction of warpage could be evaluated, and from this work came about a change in mill techniques eliminating roller leveling and substituting controlled stretching both before and after heat treatment.

4. Spars, longerons and heavy stiffeners machined all over, whether extruded or forged, generally warp so much they have to be straightened. To avoid high residual stress concentrations induced by such localized straightening, the general rule is that all such operations should be done at elevated temperatures, but hot forming is expensive and presents handling problems since ovens or other heat treating furnaces cannot be installed near all machines. Furthermore, accurate controls are necessary to prevent overheating the parts, or heating them so long that mechanical properties or corrosion resistance will be impaired.

Die Quenching has been proposed as a solution of distortion and forming problems. While die quenching will undoubtedly grow in favor, it requires elaborate and expensive facilities and its efficacy is debatable in many instances where wide variations in cross section and configuration, plus the difficulty of getting a complex section in the dies, decrease the quenching rate – again with a possible loss in mechanical properties or corrosion resistance.

In any event, such expensive techniques should be some incentive to improve methods so the aircraft manufacturer can avoid such time-consuming operations. The high costs demand a sound solution to the problem which will apply generally to all types and classes of parts without requiring trial-and-error experiments on each

individual design. How this may be accomplished will be pointed out.

Metallurgical aspects of the problem are undoubtedly as important as dimensional stability. There is a good reason why aircraft engineers are concerned with the fatigue life of their materials. They cannot take chances with human lives and they cannot arbitrarily add large "safety factors" based on assumptions; in most instances this would add weight and nothing else to the airframe. Unfortunately, too, much remains to be learned about fatigue failure of metal. There have been probably more theories advanced as to the phenomena which govern fracture corrosion, fretting and other terms related to fatigue failures than on any other technical subject. Two facts seem certain: Any disturbance in the internal crystalline structure of a metallic part which results in stress concentration is to be avoided at all costs. Furthermore surface *tensile* stresses are the arch villains responsible for the most indeterminate failures, and surface *compressive* stresses are beneficial where loads and atmospheres are conducive to stress-corrosion.

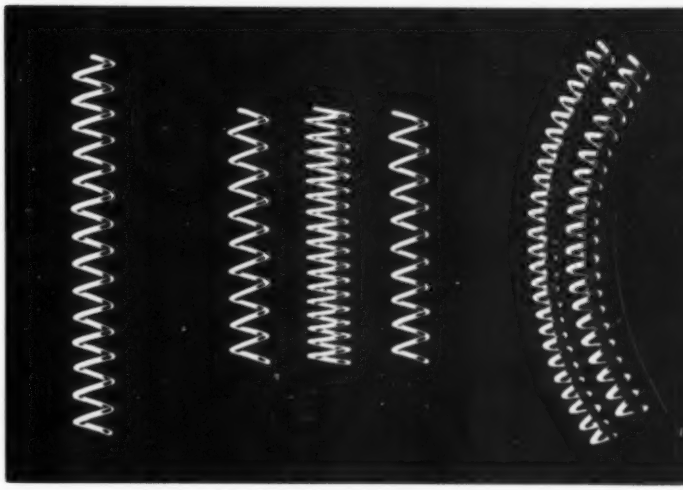


Fig. 2—Heyn's Spring Analogy and Method of Stress Determination. At center is a model of a cylinder with compressive stress in the inner layers, tensile in the outer. If the outer layers are machined off, the central core, freed of restraint, will lengthen as shown at left. If only one side of the bar is cut away, the residual stresses are rearranged and the bar bends as shown at right.

Various Difficulties Due to Residual Stresses

Forged high-strength aluminum alloy members are produced from cast ingots which have been worked in the plastic range by extrusion or rolling to billet size, and further reduced and hot worked in a series of dies intended to produce the correct shape and most favorable "grain direction". Forging is followed by a solution heat treatment, drastic quench, and aging at moderate temperatures. The drastic quench is necessary to obtain maximum properties; at the same time it results in high surface stresses. Figure 1 indicates the magnitude of these so-called "residual stresses" measured on 2½-in. rounds of aluminum alloy 122 quenched from 480° F. in various mediums, and are typical for other alloys as well. Rapid quenching puts tensile stresses of about 18,000 psi. at the center of these bars – on the order of one-third the yield of allowable design properties, as shown by figures from ANC-5* for heat treated and aged 14 S and 75 S:

	14 S (4 in. or thinner)	75 S (3 in. or thinner)
Ultimate tensile stress		
Longitudinal	65,000	75,000
Transverse	62,000	71,000
Tensile yield ((0.002% strain)		
Longitudinal	55,000	65,000
Transverse	52,000	62,000
Compressive yield stress		
Longitudinal	55,000	65,000
Transverse	52,000	58,000

Obviously, the stresses created in quenching can cause permanent deformation in the material without relieving the residual stresses. This is a fact so well known to heat treaters that it is unnecessary to belabor the point. It is worth developing the less-known fact that residual stresses may only arise from operations such as forging and extrusion.

Figure 2 is a mechanical analogy illustrating the effect of machining parts containing residual stresses. It is due to E. Heyn, a German investigator who used it in a discussion of "Internal

*ANC-5 is the bible on strength of materials used in aircraft, issued by the Munitions Board Aircraft Committee.

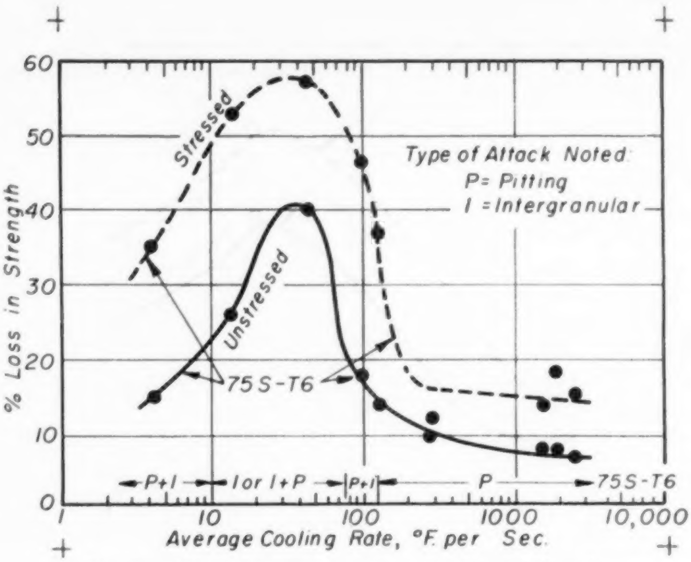


Fig. 3—Effect of Quenching Rate on Type of Attack and Loss in Tensile Strength by Corrosion of 24 S-T 4 (colored lines) and 75 S-T 6. Alloy 24 S-T 4 was subjected to 48 hr. of alternate immersion in standard $NaCl$-H_2O_2 solution; 75S-T6 to 3 months of alternate immersion in 3.5% salt solution. (L. A. Willey, ⊕ book "Physical Metallurgy of Aluminum Alloys", p. 215)

Strains in Cold Wrought Metals and Some Troubles Caused Thereby" published in the *Journal* of the British Institute of Metals in 1914.* If a part contains compressive stresses in the outer surface and this surface is then machined off, the internal tensile stresses would be relieved with a resultant elongation of the part, as indicated at the left of the central model. If only one side of the part containing internal compressive stresses is machined, then the part would distort as shown at the right of the central model.

To quote Professor Baldwin's Marburg Lecture: "It comes as no surprise to learn, then, that a residually stressed metal can warp or distort when machined or cut. The obvious curling of planed plates, or snaking of threaded rods, is readily attributed by the engineer to residual stresses. There are a number of less obvious ways in which residual stresses can work evil and because they are not readily recognized they are more insidious. Drilling radial holes into drawn rods, for example, releases residual stresses such that the hole changes in diameter slightly. These slight changes in hole size, while not affecting rough drilling operations, can cause finishing operations to break down (due to binding of drills or reamers, etc.). The rod is usually blamed for being poor in machinability."

Baldwin also cautions that "the *reduction* of tensile residual stresses is not a cataclysmic reaction that occurs suddenly at the magic touch of a straightening machine, but rather is a gradual transition depending upon certain geometric and mechanical variables. Straightening may convert surface stresses from tensile to compressive and prevent cracking there, but unless its effects have penetrated deep enough to prevent cracking *below* the surface where it cannot be found by superficial inspection, sufficient tensile stress may remain to play havoc in subsequent machining operations and with fatigue performance."

Robert F. Mehl in his article on "Recrystallization" in the 1948 Edition of ⊕ Metals Handbook, p. 259, states: "Macroscopic stresses can measurably decrease the fatigue strength of materials when such stresses are tensile on the surface, can increase fatigue life when stresses are compressive on the surface, and in a wholly similar way can be conducive to failure from stress-corrosion as in season cracking, and can lead to yielding of structural members at loads below the normal yield."

Again, Sachs and Van Horn in their ⊕ book "Practical Metallurgy", re-emphasize the critical nature of high tensile stresses in forgings and agree that a system of stresses which are tensile in nature in the interior or core may be beneficial rather than detrimental. They advise that all drilling which is feasible should be performed on forgings *prior* to heat treatment, since they found that the most common source of dangerous tensile stresses in finished components is in boring operations.

The importance of retaining compressive stresses at the surface may be gathered by the remarks of the ⊕ Subcommittee on Stress-Corrosion (Metals Handbook, 1948 edition, p. 227): "The rate of corrosion of many metals not sus-

*The illustration is adpated from those appearing in "Residual Stresses in Metals", the 23rd Edgar Marburg Lecture by Wm. M. Baldwin, Jr., before the American Society for Testing Materials (*Proceedings*, 1949, p. 539).

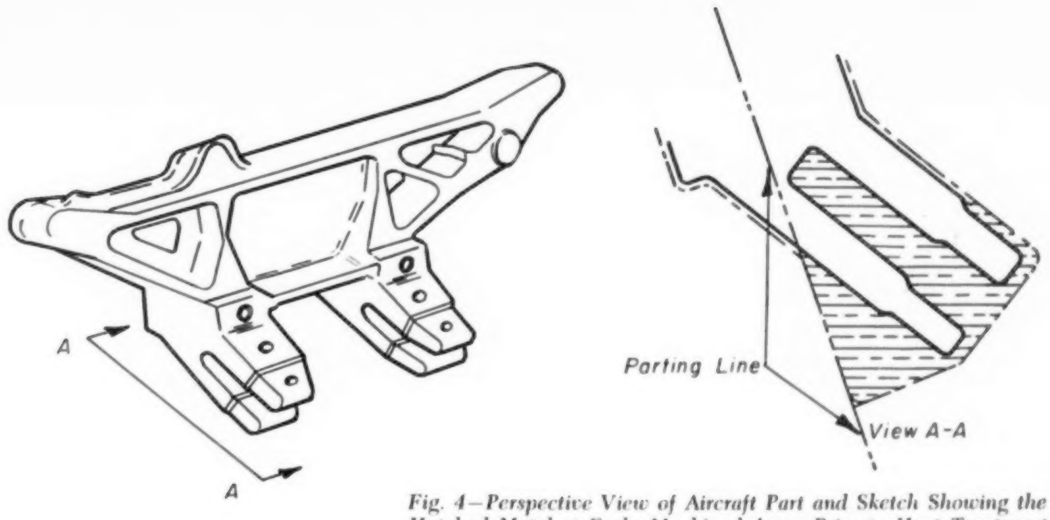


Fig. 4—Perspective View of Aircraft Part and Sketch Showing the Hatched Metal at Forks Machined Away Prior to Heat Treatment

ceptible to stress-corrosion cracking may be accelerated by high enduring tensile stresses at the surface." In speaking of the stress-corrosion of aluminum alloys in particular, Dix and Brown, on p. 228 of that same volume, note that "it is generally agreed that the stresses causing stress-corrosion failure are tensile in nature or have tensile components at the surface of the metal", and they recommend that "alloys should be in the annealed temper when subjected to severe forming operations".

Some alloys may be quenched somewhat slowly, which may produce a lower order of residual stress, but this is not generally possible with alloy 75 S, widely used in airframes. Figure 3 gives the effect of quenching rate on stressed and unstressed specimens of 24 S-T 4 and 75 S-T 6 sheet. Presenting this chart by his associate L. A. Willey, Edgar H. Dix* of Alcoa Research Laboratories does state that "high residual stresses in many irregularly shaped products of massive section, which are produced by a rapid quench, may be more detrimental to the serviceability of the product than a lower resistance to corrosion", to be expected as a result of a slower quench. The importance of stress-relieving where close tolerances must be maintained is emphasized. It is pointed out by the Committee on Relief of Residual Stress (1948 Metals Handbook, p. 237) that "residual stresses may be introduced by some types of machining, particularly rough machining. If not otherwise relieved, residual stresses will be reduced during light machining operations, since the removal of metal disturbs the equilibrium, with attendant readjustment and warping."

The combination of slow quench (permissible) plus the high aging temperature stress-relieves the 14 S alloy to a considerable degree. However, the low aging time and temperature which gives optimum physical properties to 75 S does not appreciably stress-relieve the aged alloy; consequently, heat treated 75 S parts are especially likely to contain residual stresses. Authorities have required shot-peening of machined parts of 75 S wherein there is an indicated residual stress after machining amounting to 20% of the yield strength. While the Committee on Relief of Residual Stress states that "surface compressive stresses which may be introduced by shot-peening, cold forming and other techniques may increase resistance to fatigue", a warning is given that excessive peening may produce high tensile stresses *below* the surface which may cause failure (see Metals Handbook, 1948 Edition, p. 241).

As previously mentioned, residual stress can contribute to stress-corrosion. C. W. George and Bruce Chalmers† conclude that "corrosion fatigue failures are similar to stress-corrosion in that it is the tensile stress part of the cycle of fluctuating stress which causes breakdown of the structures." The importance of this phenomenon is indicated by their statement that "a threshold for stress-corrosion cracking failure occurs at

*In "Thermal Treatment of Aluminum Alloys", published in the book, "Physical Metallurgy of Aluminum Alloys", 1949, p. 214 and 217.

†"Stress-Corrosion in Relation to Aircraft Components;" Symposium on Stress-Corrosion Cracking of Metals; joint meeting of the American Society for Testing Materials and the American Institute of Mechanical Engineers, August, 1945.

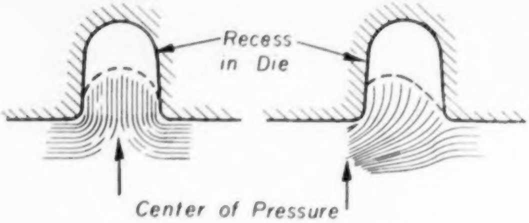


Fig. 5 – Location of Center of Pressure Influences the Filling of Recesses and Flow Lines

about 25% of the yield strength for an aluminum alloy exposed three times a day to a spray of natural sea water."

It can be concluded that the experts agree that it is, to say the least, undesirable to disturb the structures by machining any more than is absolutely necessary. Neither should other variables be added, such as the mismatch of varying cuts, tool marks in fillets, surface scratches, and possible loss of properties due to the frictional heat induced by the use of dull or improperly designed tools.

That the latter may be of importance is proven by tests on four sets of duplicate specimens of 75 S-T 6, prepared by milling. One of each set was machined with a sharp cutter, the other with a dull cutter. The test pieces milled with sharp tools had tensile strengths of 86,300 to 90,000, and yield strengths of 77,700 to 82,500. Test pieces milled with dull tools had tensile strengths of 78,000 to 82,000 (a reduction of 10.1%), and yield strengths of 67,000 to 70,000 psi. (a reduction of 14.1%).

Techniques for Minimizing Residual Stresses

Since the facts agree that it is desirable to do as little machining of heat treated forgings as possible, current forging practices must be modified. If we adopt the premise that to utilize the presses to the maximum we must modify current methods and techniques, then we can approach the problem of producing a part to design limits with open minds.

Aircraft engineers demanded larger presses not only because of size limitations but also because accuracy limitations lead to weight penalties or excessive machining. Rejection costs were becoming unbearable. It is desirable that a forging be symmetrical; however, the very adaptability of the forging process makes it difficult to convince designers that reasonable symmetry is essential. In instances where radical changes of section or extremely unsymmetrical shapes are

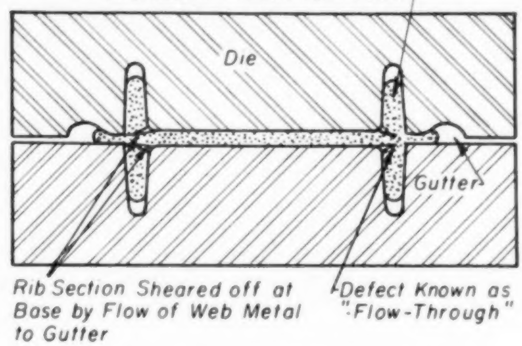


Fig. 6 – "Flow-Through" Is a Limiting Factor in Forging a Thin Web Between High Ribs

necessary, some machining will have to be done on the forgings.

The problems of plastic flow, ejection of the part from the dies, and factors relating to die life (such as temperatures, lubrication and area) all affect the configuration which may be forged. For many designs, machining can be used as a tool to obtain the required configuration at least cost and without disturbing the forged

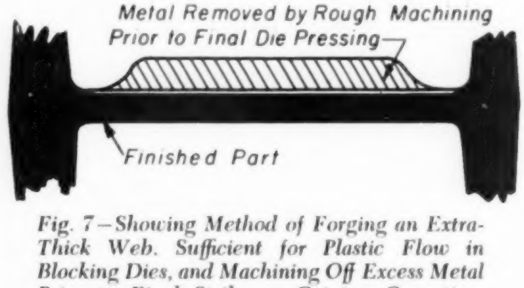


Fig. 7 – Showing Method of Forging an Extra-Thick Web. Sufficient for Plastic Flow in Blocking Dies, and Machining Off Excess Metal Prior to Final Strike or Coining Operation.

surfaces. Careful study of current designs will bring to light many instances where this can readily be done.

In the early part of this article a tabulation gave the properties which can be expected for 14 S and 75 S in thicknesses of less than 3 or 4 in. If the design contains large bosses, lugs and other regions which are thicker than the sections for which good transverse properties or elongation can be guaranteed by the producers, it naturally follows that the rough boring of holes or rough slotting of clevises prior to heat treatment is the only method of reducing the section to a thickness of metal which can develop satisfactory properties after quenching and aging. This is

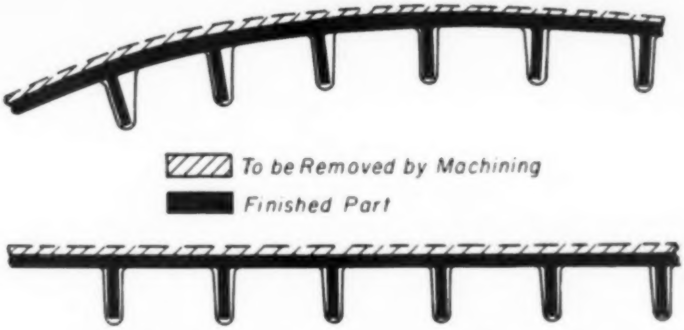


Fig. 8—Forging to Contour (as at Top) Requires Expensive Dies and Much Difficult Machining to Remove Extra Metal Required to Fill Draft Angles of Inclined Ribs. It is better to forge and machine flat (as at bottom), and quench in a contoured die

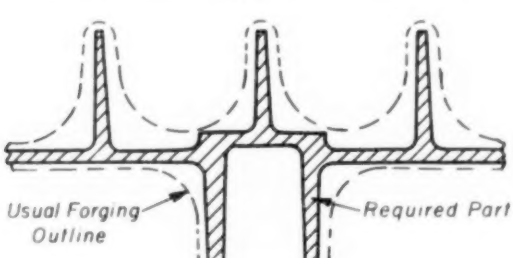
fairly common practice today for 75 S and is accepted without question. However, machining has been done for this purpose only and not for masses whose properties would meet requirements without machining. Neither has it been done simply to eliminate distortion or scrap occurring during machining.

Figure 4 on p. 85 illustrates an actual aircraft part which is reduced by machining subsequent to forging and prior to heat treatment; the hatched area shows the metal machined away.

In designing forging dies it is important that the initial blocking operations be performed on billets or shapes of a carefully calculated volume in order that ribs may be properly filled. This is difficult for very complex forgings and trial-and-error methods consume large quantities of time. If there are large flat webs between ribs, the required pressure may exceed the strength of the die or the capacity of the press; the webs will not thin down and metal will not flow into the ribs. This effect is noted in Fig. 5. Even using the rule of 30 tons per sq.in., a designer is approaching the upper limit of the heavy presses with a web of only 1500 sq.in. As webs become thinner, the phenomenon known as "flow-through" (Fig. 6) may occur. Lastly, shearing stresses caused by flow of metal in opposing directions in the webs may lead to defects at the parting line.

It is possible and simpler to fill the ribs in a first finish die, retaining sufficient metal in the web so it will flow in a plastic manner without shearing or flow-through, as shown in Fig. 7. Next operation would be rough machining of the web, close to final configuration, retaining enough metal so it will move sufficiently in the finish die to bring the web to size. This may require an additional upper die, but its cost will be amply justified by the results obtained.

Fig. 9—Deep Pockets Usually Are Nothing but Dents in a Forged Surface. It is recommended that they be rough machined in the blocked bar and finish forged with minimum draft



There is another advantage to be gained by in-process machining of webs. Normally, thickness tolerances for large forgings are fairly large. Assume that a forging has a web tolerance of plus 0.060, minus 0.020 in. If such forgings consistently run to the high side (as they usually will), each part put into the airplane will be substantially above the calculated weight. By rough machining the webs of the forgings to a predetermined thickness after blocking and finish operations, it will be possible, by carefully controlling the finish forging cycle, to produce webs of close tolerance and thus considerably reduce the weight.

Still another advantage is obtained for thin forgings of large area such as are desired for wing panels and the like. Generally, these must meet the contour requirements of some airfoil. To forge these to contour not only increases the cost of the dies but also increases weight in the form of material necessary to fill the larger draft angles of any stiffening elements not exactly normal to the parting line. By forging flat, as shown in the lower part of Fig. 8, each vertical stiffener can be made with minimum draft. The desired skin thickness can be achieved by machining in the flat. After heat treatment, the part may either be quenched in a contoured die or, after a regular quench, struck in a contoured die. All that remains is to machine those attaching flanges necessary to fit up the part on assembly accurately.

Small pockets of any depth create excessive pressures and, even though carefully considered in the design, may lead to early die failure. Such forged pockets generally are only dents in the surface and require full machining by laborious end-milling techniques (Fig. 9). If this dent in the blocked forging is shaped by rough machining to remove excess material, finishing the forging with minimum draft will usually eliminate finish machining operations.

Trusses, with cross braces of varying sizes, present a problem in mass distribution during blocking operations (Fig. 10). If these are produced from flat stock (as is normally done), pressures are excessive over the areas between members from which the metal is finally to be removed. It is sometimes desirable to profile such flat shapes prior to blocking so the pressures are directed to the regions where needed. In others, such profiling is best acomplished after blocking and before finishing operations. These are common practices to facilitate forging operations, rather than to eliminate excess material where the advantage lies mainly in the reduction of finish machining to remove flash and draft for reasons of weight only.

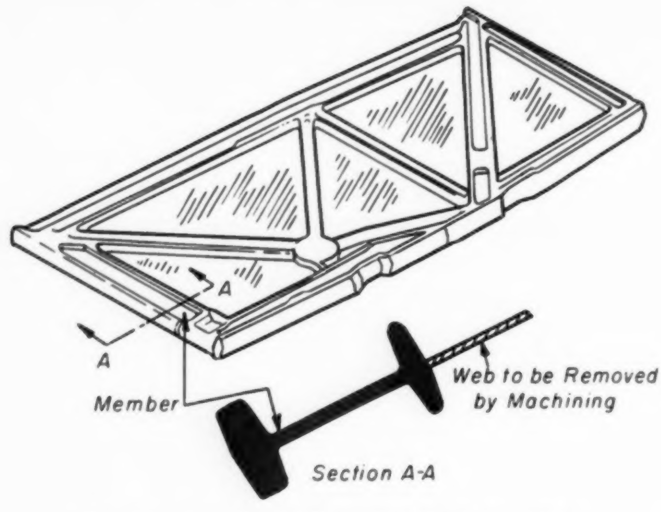


Fig. 10—Truss Forged From Flat Stock, Remaining Webs to Be Cut Out. If this is done after blocking and before finish forging, part can be forged to closer tolerances and finish machining is minimized

Summary and Conclusions

An objective analysis makes it clear that in-process machining is an expedient whose proper use will eliminate or at least reduce many current difficulties in the production of large forgings. Certainly not every heavy forging produced may warrant or require in-process machining, but there are many designs which economically demand such processing.

Furthermore, since it can be safely assumed that complexity will increase with increased knowledge of the heavy presses, in-process machining will, in time, become an integral function of the forging process.

There are two general advantages to be gained from in-process machining. These advantages are, first, an improved product, and second, greater economy and improved operation of the forging process.

Contributing to an improved product are:

1. Improved dimensional stability by decreasing the amount of heavy machining subsequent to forging and heat treatment.

2. Improved strength and fatigue life, since structural components may retain as-forged surfaces which formerly were cut away after the forging was completed.

3. The likelihood of parting plane defects in certain shapes is reduced by machining between blocking and final forging.

Improvements in the forging process to be gained from in-process machining are:

1. Closer dimensional tolerances and smaller draft angles in many designs where pressure limitations and plastic flow would otherwise be controlling factors.

2. Die life can be improved by reducing the pressures necessary to form small pockets, thin webs and deep ribs.

3. Complex shapes may be produced with fewer costly preliminary operations.

4. Forgings of minimum weight may be supplied the user.

Thus, it is eminently desirable to do a minimum of machining on large forgings subsequent to heat treatment, and as much machining as possible during the forging cycle, to minimize detrimental effects of residual stresses, economize on finished weight and at the same time improve operating procedure and economy.

Fig. 1 – Automotive Clutch Bearing Races Being Quenched One at a Time in Brine

Production of bearings was increased 350% with half the manpower by changing from 21 batch-type pack carburizing furnaces to two salt furnaces for liquid carburizing.

Liquid Carburizing

*By THOMAS M. DOUGHERTY**

During the period immediately following World War II, there was urgent need for increasing our heat treating capacity, especially in connection with carburizing. It was found that the amount of work handled by the heat treating department would have to be raised by more than 75% to cope with the increased volume of manufacture. Better metallurgical control was needed during carburizing and the time for carburizing had to be shortened. In addition, the physical size of the carburizing department had to be held to a minimum.

Bearings produced by the Bearings Co. of America Div., Federal Mogul Corp., are used in automotive, machine tool, agricultural and ordnance components. These bearings are of the single and double-row ball types, as well as angular contact and pure thrust, and are made in the company's plant at Lancaster, Pa. Two kinds now in production, the automotive clutch release (of A.I.S.I. C 1018) and those for agricultural equipment (C 1117 and C 1118), have raceways that are carburized to customer specifications. Hardness required of these items is Rockwell C-60 to 62 after tempering with a case depth of 0.054 to 0.060 in. prior to finish grinding. Distortion during heat treatment must be held to a minimum to avoid excessive grinding that would result in uneven case depths on finished raceways.

In the early postwar period 21 batch-type furnaces were used for the pack carburizing treatments. Time for the treatment (at 1750° F.) varied between 9 and 12 hr., depending on the ability of the steel to carburize as determined by laboratory tests. To this soaking time was added the delay necessary for cooling, reheating, and finally, quenching and tempering. Total furnace output was limited to 10,000 pieces per day.

Two liquid carburizing furnaces (made by Ajax Electric Co.) were installed, together with "stabilizing" pots, liquid tempering baths, and rinse and quenching tanks. These units were placed parallel to each other and in direct line with the equipment for blanking, coining and machining. With this change in heat treating facilities six operators (half as many as formerly) turn out 35,000 pieces of carburized bearing races in 24 hr., a 350% increase in production over the former method.

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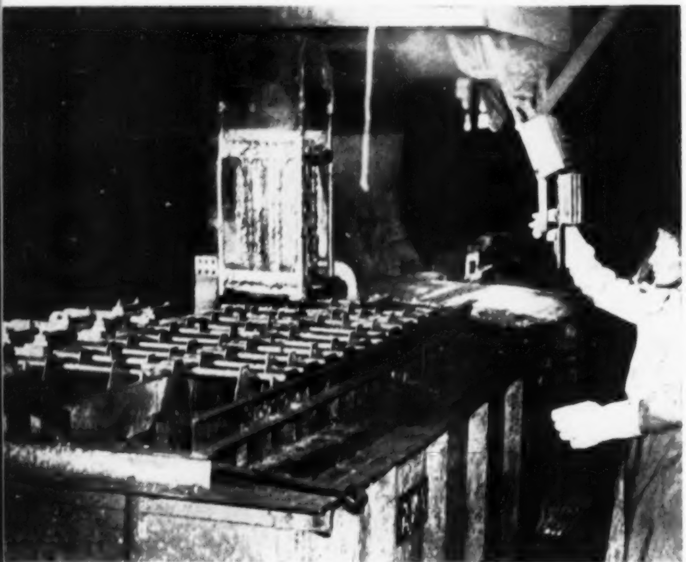


Fig. 2 – Load of Bearing Races Being Removed From Salt Bath Carburizing Furnace. Saw-toothed positioners support 23 fixtures in the furnace

Both the automotive clutch and the annular races for agricultural equipment receive essentially the same treatment, the details differing according to uses and customers' specifications. Machined, inspected, and laboratory tested races are loaded on fixtures and charged into the liquid carburizing furnace by overhead electric hoist. The custom-built carburizing unit, controlled at 1700° F., has inside bath dimensions of 8 x 3 x 2½ ft. deep. Full charge of salt is 6500 lb. at operating temperatures. The parent or bulk salt is a commercially prepared mixture of alkali chloride and alkaline earth chloride to which is added commercially prepared carburizing salt in the form of pellets containing approximately 35 to 36% sodium cyanide. Activity in carburization is promoted by the presence of barium compounds.

The holding time for carburizing averages about 1 hr. for each 0.010 in. of case depth, this average being based on a 6-hr. hold. Actually, the carburizing action slows somewhat after 3½ to 4 hr. The maximum depth developed is between 0.055 and 0.065 in., this being on the bearing raceways for the clutch release units. Shallowest zones produced are on pulley sheaves (of A.I.S.I. C 1010 or C 1015), these being 0.015 in. deep. Samples of each lot of steel are subjected to tests simulating actual carburizing conditions and these are then measured in our laboratory for grain size, ability of the steel to carburize and the time required, hardness developed prior to tempering, and quality of the case. These characteristics form the basis for the heat treating specifications that are issued for each heat of steel. Various heats of steel are kept separate until they have passed successfully through heat treatment.

Once the carburizing cycle has been reached, the races are transferred to the "stabilizing" unit, a bath of neutral salt controlled at 1450° F. Races are allowed to drip carburizing salt for a few minutes prior to immersion in the stabilizing bath. The purpose of this bath is to bring the temperature of the work to 1450° F. so that less distortion will occur from the subsequent quenching operation. The benefits of quenching from a lower temperature with regard to reduction of distortion justify the costs of this additional procedure. An additional benefit of its use is the rinsing action of the salt wherein water insolubles carried from the carburizing bath are rinsed free of the raceways.

The stabilizing bath contains an alkali chloride mixture having a working range between 1300 and 1700° F. Holding time is 5 min. This bath is rectified once a week by removal of at least one third of its volume which is replaced by fresh salt. This is a necessary safeguard against the building up of barium carbonate and small percentages of sodium cyanide from the drag-out of the large furnace.

After the load has been brought to the lower temperature, it is transferred to the quenching station where the races are dumped in cascade fashion into a violently agitated solution of 10% brine. The quench bath is held to below 90° F. by means of specially designed cooling plates having circulation of cold water through labyrinths. These plates are situated at several points in the quench tank in such a way as not to interfere with the agitation of the water.

The final treatment is a 1-hr. tempering done at 370° F. in a low-temperature bath containing nitrate-nitrite salts. A hot water rinse before and after tempering, and a cleaning by grit blasting complete the cycle. Time in the cycle is never more than 7½ hr. Six men now heat treat in a 24-hr. day more than 3½ times as much work as 12 or 13 men handled formerly.

The concentration of all the company's carburizing in two compact and efficient units has simplified problems of instrumentation, scheduling of the work and control over quality. The uniformity of the heat treatment with these salt furnaces is consistently reproducible.

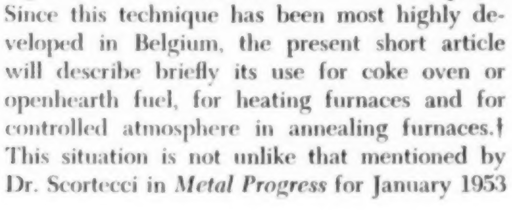
Methane for Openhearth Fuel

*By D. W. GILLINGS**

"Firedamp" (methane), an explosion hazard in coal mines, is now being systematically extracted from the coal seams underground, supplied to an extensive pipeline network in Belgium and used to heat openhearths, heating furnaces and coke ovens.

SINCE THE WAR a new technique has been established in Europe for controlling "firedamp" in coal mines – a matter of some interest to readers of *Metal Progress* only because the combustible gas is converted from an ever-present mining hazard to a valuable fuel in the steel plant. Since this technique has been most highly developed in Belgium, the present short article will describe briefly its use for coke oven or openhearth fuel, for heating furnaces and for controlled atmosphere in annealing furnaces.† This situation is not unlike that mentioned by Dr. Scortecci in *Metal Progress* for January 1953 (p. 93) wherein he described the metallurgical uses of methane from drilled holes into a gas horizon near Milan – a new resource of the greatest importance to Italy which otherwise imports nearly all its fuel.

Fig. 1 – Sketch Showing Oil-Methane Burner Discharging Into Heated Air From Regenerators to Fire an Openhearth



However vital the firedamp problem is to mining engineers, it suffices our present purpose to say that methane is exuded from the coal measures in certain "gassy" mines and the traditional means of controlling it is to sweep it out of the working by adequate ventilation and dilution below the ratio where it ignites. In the new practice of gas drainage, first tried in Western Germany in 1943 in areas which contain a series of parallel coal seams, several series of inclined, radiating holes are driven from as many centers near the working face ahead into the next seam above the roof. These holes are capped, connected to a suction main and methane pumped out in useful concentration.

So much valuable gas is secured in this way that a network of pipelines has been laid, paralleling the "gas grid" which has been supplying coke oven gas to the whole of Belgium's southern industrial belt. Methane is now used directly in some units of the steel industry, but other consumers of coke oven gas have not yet – at least in considerable numbers – converted the burners so

*National Coal Board, London, England.

†Acknowledgments are gratefully made for technical information to M. Lambilliotte of Usines Gilson S.A., M. Gohmann of Charbonnages de Monceau Fontaine S.A., the directors of Distrigaz S.A. Brussels and "Inichar", Liege, and to many colleagues in European coal industries. The descriptions are the authors' and are not necessarily endorsed by the National Coal Board.

they will handle this gas, whose calorific value (1014 Btu. per cu. ft. for pure CH_4) is more than double that of coke oven gas.

Direct Combustion

Direct combustion of undiluted colliery methane is regular practice in the steelworks of Usines Gilson, S.A., at La Croyere, Belgium. As mentioned above, methane has a high calorific value relative to coke oven gas but the maximum flame temperature is not very different. In openhearths the usual practice for burning coke oven gas is adopted – the air only being preheated. The furnaces at La Croyere have been converted from twin regenerators and uptakes, so that both regenerators and uptake carry air; the gas is burned without preheating in a single central burner as shown in Fig. 1. Methane must not be preheated else it cracks and deposits much carbon on any hot surface. The steelmakers attach much importance to maintaining excess air over the metal bath to insure oxidizing conditions, and to complete the combustion of CO formed during the refining reactions.

A proportion of fuel oil is also added to the gas flame both to raise the over-all heat generation and to insure adequate flame luminosity for good radiation efficiency. Figure 2 shows this dual fuel burner. Although this operating method was developed for this specific application, the need for an adequately luminous flame is well appreciated. The combination of oil and methane heating has been adapted for the extended use of natural gas in Italy as already noted.

Another factor which is of great importance is the freedom from sulphur. Sulphur is rarely present in methanes from collieries. There is, of course, no certainty that this would always be true, as it is known that some high-sulphur coals emit gases containing sulphur. The general experience is, however, that firedamp is considered a sulphur-free gas and any exception is unusual. This is in contrast to petroleum natural gas, which often has a high sulphur content, although sulphur-free natural gas is also reported.

Methane is also used at the Gilson steel plant in reheating furnaces for ingots and blooms. The furnaces themselves are conventional, the special fittings being confined to the burners and the control of gas. A burner with highly turbulent air entry is installed (Fig. 3), the air being under pressure and preheated by a metallic recuperator. In changing from coke oven gas to methane, the gas ports have to be reduced and the air supply somewhat increased. In actual experience, it was impossible to convert with unimpaired efficiency and some time elapsed before methane firing was regular and fully effective. Forced draft rather than induced draft greatly assisted, since ignition may be difficult in gases low in hydrogen content and with low flame velocity. The effect of low flame velocity can be minimized by operating with heated air, and since a large volume of air is needed for combustion of methane, the preheated air stabilizes the methane flame very markedly. For related reasons, it is recommended that all units burning methane be adequately safeguarded by flame traps or flash arresters in the supply lines. The above limitations apply with greater importance to colliery methane than to other natural gas, since the latter frequently contains higher paraffins, sometimes in considerable proportion.

Controlled Atmospheres – While the application to furnace heating is so far the main direct use of colliery methane in the Belgian steel industry, some thought has been given to the exploitation of the reversible reaction

$$CH_4 \leftrightarrows C + 2H_2$$

which takes place with relative facility at the temperatures around 1750° F. (950° C.) encountered at the surface of hot firebrick. This can provide a source for a protective atmosphere for some annealing requirements, and is used in this manner with firedamp as a source of methane in much the same manner as natural gas is used in the United States.

Substitution of Methane for Coke Oven Gas – While the direct use of methane as just described is perhaps the most striking adaptation to steel plant needs, there are, of course, other important uses, and of these, addition to a normal supply of coke oven gas is of most interest. Any mode of interchange or supplement to coke oven gas requires a conversion from a slightly diluted methane whose calorific value is about 900 Btu. per cu. ft. to one having 450 to 525 Btu. per cu.ft. This

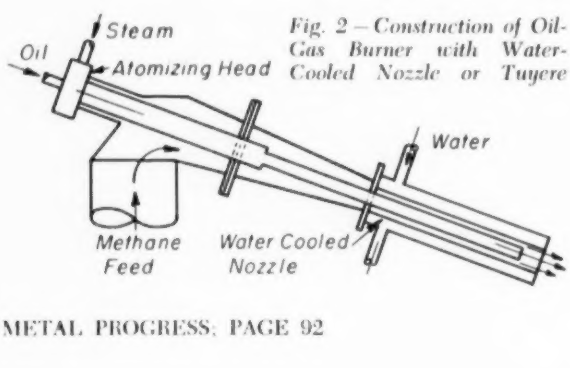


Fig. 2 – Construction of Oil-Gas Burner with Water-Cooled Nozzle or Tuyere

conversion has been achieved in several ways.

Dilution – In general, the properties of methane are too far removed from those of coke oven gas for unrestricted mixing. Further addition of blast furnace gas can yield a mixture of correct calorific value, but its flame velocity, as well as its more elementary characteristics such as density, differ profoundly from those of the normally manufactured coke oven gas. If only a small percentage of methane is available, dilution with air is permissible, but any schemes leading to extensive dilution with coke oven gas do not appear practicable.

Re-forming – Methods more satisfactory than dilution are already available and have been frequently applied. Most usual is the thermal cracking process, in which methane is transformed by reaction at about 1650° F. (900° C.) with oxygen and steam, and in part by its own molecular rearrangement, to a mixture that consists primarily of carbon monoxide and hydrogen.

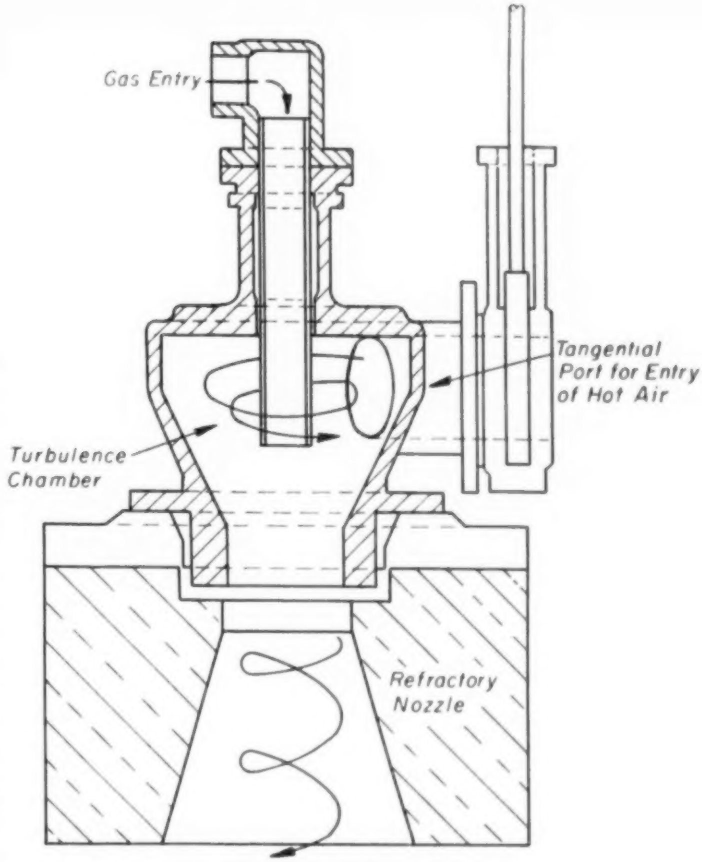


Fig. 3 – Layout of Burner for Reheating Furnace

These reactions have been carried out in special reactors, as well as in chambers adapted from existing coke ovens, filled with hot coke and nickel catalyst. As is well known to the American steel treating fraternity, the composition of the gas can be varied by choice of air-steam ratio and controlling the input of heat into the reacting system. Thus the process can yield gas whose calorific value and other important properties are indistinguishable from coke oven gas.

Underfiring Coke Ovens – From the purely technical viewpoint, a simple and efficient use of colliery methane is for the heating of coke ovens. The effect is to convert the methane with its theoretical calorific value at 1014 Btu. per cu. ft. to an equivalent thermal yield of gas of the preferred industrial gas calorific value (500 Btu. per cu.ft.). The colliery methane can be used without preheating as in a steelworks furnace. This procedure has been adopted at the central coking plant at Tertre, near Mons, Belgium, a relatively large installation with existing provision for firing methane. The same scheme for using methane under coke ovens at some of the Belgian steelworks in the neighborhood of Charleroi has been suggested, but instead, installations of cracking plants are favored. Similarly, the proposals to use methane mixed with blast furnace gas at individual plants have been set aside in favor of re-forming.

Conclusion – It would appear, therefore, that a serious and ever-present colliery hazard has been converted into an economic asset of noteworthy proportions. So far, the steel and coking industries have been the largest consumers of untreated methane, primarily because the individual furnaces consume such large quantities of fuel that conversion of the burners so they handle a rich gas is relatively inexpensive. More widespread distribution to smaller customers will probably require fairly large re-forming plants to convert the methane into gas of about half its calorific power, capable of being used efficiently in existing domestic equipment.

Effect of Sigma Phase on Properties of Alloys

by ADOLPH J. LENA*

The magnitude of the effect which sigma may have on mechanical and corrosion properties of stainless steels depends not only on the amount present but also on particle size and distribution. General conclusions are given regarding effect on notch-sensitivity, ductility at room and elevated temperature, tensile strength and results of corrosion tests.

This is the second of a three-part article on the formation of sigma and its effect on the properties of alloys. The first part (printed in the July 1st issue of *Metal Progress*) pertained to the compositional limits of sigma formation in alloys which were essentially of the stainless steel types; that is, steels which are basically iron-chromium, iron-chromium-nickel or iron-chromium-manganese alloys. This part will explain the effect which sigma exerts on the mechanical, physical and corrosion properties of metal alloys, particularly in regard to stainless steels.

Effect on Mechanical Properties

The work of Bain and Griffiths not only revealed the existence of sigma for the first time but also disclosed many of the features which are characteristic of this phase. Chief among these are the extreme hardness of the sigma phase itself and the embrittlement which is often associated with its presence. On account of its high hardness (Rockwell C-68.5), sigma is somewhat friable and often shatters under the load impressed during a hardness test. High-chromium irons containing a continuous network at grain boundaries suffer severe losses in ductility but these are recovered by heating to a temperature sufficiently high to dissolve the sigma.

Sigma in Type 430 (17% Cr) is present in very small amounts, and very long times are required for its development; therefore, its presence has not generally been considered a factor in the embrittlement of these steels. There are some who believe that 885° F. embrittlement of ferritic steels is associated with sigma formation; therefore, the ability of sigma to form in Type 430

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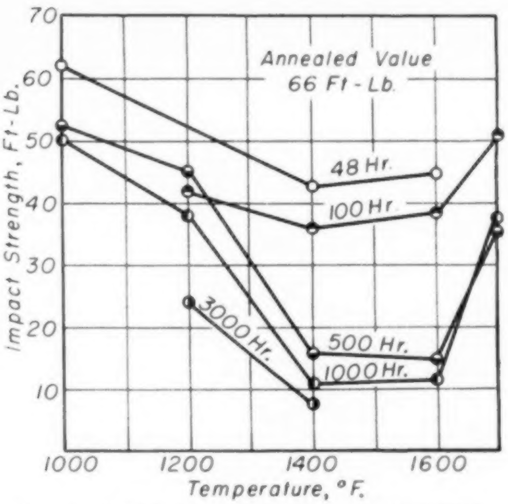


Fig. 1 – Effect of Aging on Room-Temperature Impact Strength of Type 310. Lowered impact strength is due primarily to sigma formation. (From "Symposium on the Nature, Occurrence and Effects of Sigma Phase", by G. N. Emanuel, American Society for Testing Materials, 1951, p. 82)

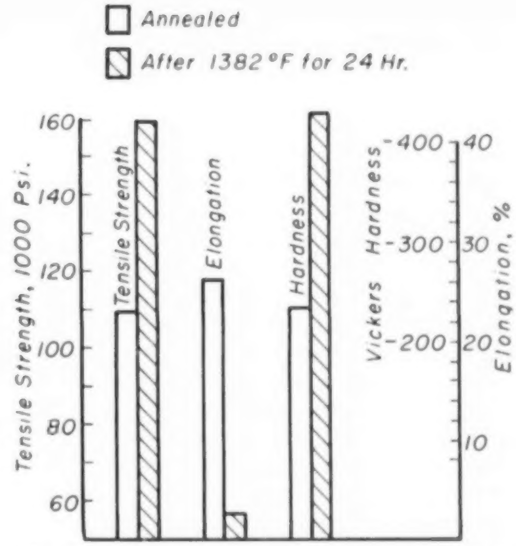


Fig. 2 – Changes in Room-Temperature Properties Due to Formation of Sigma in a Steel of 0.10 C, 1.42 Si, 0.59 Mn, 4.29 Ni, 25.5 Cr and 1.63 Mo. (E. B. Bergsman and E. Ericsson, Varmlaudska Bergsmannaforeningen Annalen, 1942, p. 31)

below 1200° F., may be an important factor in its susceptibility to 885° F. embrittlement. Type 446, because of its higher chromium (27%), is more susceptible to sigma embrittlement, and failures of boiler tubes after long periods of service have been reported. The embrittlement may be so extensive that the steel may shatter like glass when dropped.

Although sigma itself is very hard, hardness of the steel may be only slightly affected, but notch sensitivity is generally greatly increased. This effect is particularly bad in high-chromium ferritic steels, for they are inherently notch-sensitive. It appears to be a characteristic of sigma to exert a greater effect on impact strength than any other property and many reports have appeared of the impact strength of stainless steels being lowered considerably by the presence of sigma without major changes in other properties. In particular, hardness and tensile strength are often either not affected or only slightly altered and are poor tests for detecting sigma.

Figure 1 shows the effect of time and temperature within the sigma formation range on the room-temperature impact strength of Type 310. The 1000-hr. treatment at 1400° F., which lowered the impact strength by 83%, had essentially no effect on the tensile strength, but did reduce the elongation in tension by 36%. Similar effects have been observed in other types of stainless steels. Several investigators observed only a slight increase in the hardness of an 18 Cr, 8 Ni, 3 Mo, 1 Ti steel, but a very severe decrease in bend angle and impact strength as a result of sigma formation.

It would be misleading to believe that hardness and tensile strength are always only slightly altered by sigma, for considerable increases in strength can be produced in many steels. An example of the magnitude of the change which is possible is shown in Fig. 2. Not only the amount but also the distribution of sigma is of primary importance in determining the effect it may have on mechanical properties. This is substantiated by the work of J. J. Gilman (*Transactions* ⊕, Vol. 43, 1951, p. 161) who found a good correlation between hardness and the logarithm of the average free path of the matrix in sigma-containing high-chromium steels, proving that hardening is due to the dispersion of the sigma and not to some intermediate stage as is sometimes found in the age hardening of nonferrous alloys.

Effect at Elevated Temperatures – Since sigma may form in a number of stainless steels during service at elevated temperatures, it is often necessary to consider its influence on the properties at such temperatures. Furthermore, there has been some interest in the possibilities of beneficially using sigma for strengthening purposes in steels for applications where strength

at elevated temperatures is a requirement. An example of this strengthening is shown in Fig. 3 for two annealed steels after periods of 15 min. and 20 hr. at 1292° F. Of the two steels, only steel B was capable of forming sigma within 20 hr. at 1292° F. and the data can be compared with those of steel A which represent the mechanical properties at 1292° F. in the absence of sigma. This is true of all but the hardness test which was measured at room temperature after testing. Steel B has a much higher tensile strength after 20 hr. at the elevated temperature than steel A and a much higher hardness at room temperature after aging.

Although its elongation is less than that of steel A at 1292° F., it is still greater than at room temperature in the absence of sigma. This would lead one to believe that sigma is not as harmful in destroying ductility at elevated temperatures as at low temperatures. However, results of impact tests do not support this assumption since impact strength at 1292° F. is much lower than the initial strength of the steel. A similar effect has been reported for the impact strength of Type 310 in the range of 1200 to 1700° F.

Another example of the strengthening effects of sigma has been reported for an alloy of 60% chromium, 25% molybdenum and 15% iron which is capable of sustaining a load of 30,000 psi. at 1600° F. for 400 to 500 hr. A recent study by J. D. Nesbitt and W. R. Hibbard, Jr. (*Journal of Metals*, Vol. 5, 1953, p. 1149) of the Fe-Cr-Co-Ni system revealed that the strongest alloys are those containing sigma.

Because steels which contain sigma retain some ductility at elevated temperatures, they may be used in applications where resistance to shock is not a requirement. Type 310, with additions of silicon to increase its resistance to oxidation and carburization, has been successfully used at high temperatures and very few failures attributed to brittleness have been reported. When such steels have been in service for extended periods at 1100 to 1700° F., they should be handled with care when cooled to room temperature and should be protected from shock.

The hardness of sigma confers wear resistance to a steel and several steels have been devised which make use of this property for applications where abrasion is a problem. Two of the most common steels are Type 314 and one designated as XCR which contains 0.40 C, 4.75 Ni, 24 Cr and 2.75 Mo. The latter has been used for automotive exhaust valves.

It has been said that over half of the production of heat resistant castings is from alloy types that can contain the sigma phase. Although sigma is not always detrimental, it is avoided wherever possible because its presence reduces resistance to creep and causes cracking and distortion due to thermal fatigue.

An accurate evaluation of the effects of sigma on the creep and rupture strength of austenitic stainless steels is difficult because of other structural changes which may occur concomitant with sigma formation. It has been observed that the properties of 18-8 stainless steels after long times at high temperature are sensitive to structural changes which may include the formation of ferrite, carbides and nitrides as well as sigma. These steels also absorb appreciable amounts of nitrogen from the air during testing. Much of the superiority in the creep strength of Type 347 over plain 18-8 steels has been attributed to the precipitation of sigma phase in a critical particle size. The reason advanced in support of this is that plain 18-8 and 18-8 with columbium have essentially the same strength at temperatures where sigma is unstable or extremely limited in amount and that the differences in strength are much less when the conditions permit rapid growth and coagulation of the sigma precipitate. A contributing effect which sigma may exert in the strengthening of Type 347 may be related to its preferential formation in delta ferrite and the resultant replacement of low-strength delta ferrite by the stronger sigma. The possibility of using sigma as a matrix strengthener for high-temperature service has been discounted by some authorities in this field because it destroys accurate dimensions and decreases fatigue resistance to cyclic stresses.

Data on the effects of sigma on creep strength for Type 314 (which may contain as much as 40% sigma with proper heat treatment) have been obtained by Guarnieri, Vawter and Miller (⊕ *Transactions*, Vol. 42, 1950, p. 981). These data are summarized as follows:

1. Sigma may increase the creep strength up to 1400° F. for short-time uses involving deformations on the order of 1% per hr.

2. At slow rates of strain, and hence long service applications, sigma decreases creep strength.

3. Sigma materially increases the short-time tensile and yield strengths.

4. Sigma decreases room-temperature ductility, but this is increasingly restored at temperatures above 1100 to 1200° F.

5. Austenitic grain size exerts an equal if not greater effect than sigma on the high-tempera-

ture properties of this steel, with a fine grain size lowering the long-time creep strength and raising the short-time tensile and yield strength.

6. The pattern of distribution and fineness of the sigma particles substantially affects the magnitude of their influence on strength and ductility.

A similar effect has been observed (decrease in the long-time creep and rupture strength) in Type 309 (25-12 Cr-Ni), but was not as pronounced as in Type 314 because of a smaller quantity of sigma.

Physical Properties of Sigma

The nonmagnetic characteristic of sigma has been used by numerous investigators as a means for following the transformation from a magnetic ferrite to a nonmagnetic sigma in ferritic and duplex ferritic-austenitic steels. Without the support of metallographic or X-ray evidence of sigma, magnetic studies alone are subject to criticism since it has recently been shown that the delta ferrite in some austenitic steels which are capable of sigma formation transforms preferentially to carbide and austenite with partial or complete loss in magnetism. (See Part I.) It has been reported that the sigma which develops in an 18 Cr, 8 Ni, 3 Mo, 1 Ti steel possesses a Curie temperature of approximately −113° C., below which it is ferromagnetic. It has also been found that the precipitation of sigma lowers the electrical resistance of steels.

Effect on Corrosion Properties

The influence of sigma on the corrosion resistance of stainless steels has not been studied in detail and not much quantitative data are available. Generally, sigma reduces the corrosion resistance of both ferritic and austenitic steels to a relatively small extent and the decrease is perceptible only when alloys containing sigma are exposed to very corrosive conditions.

Sensitized 18-8 Mo steels (Type 316 and 317) with less than 0.01% carbon are immune to intergranular corrosion due to carbide precipitation as determined by the Strauss test (10% $CuSO_4$, 10% H_2SO_4), but corrode intergranularly when tested in boiling 65% nitric acid. The intergranular attack in steels of this type has been associated with the presence of sigma which is capable of developing at the grain boundaries in as short a time as 10 min. at 1380° F. In low-carbon steels of the same chromium and nickel contents but without the molybdenum, no sigma precipitates during short-time sensitization and these are immune to intergranular attack in both the

Fig. 3 – Effect of Sigma on Mechanical Properties at 1292° F. Steel A—Not Subject to sigma formation; 0.21 C, 0.68 Mn, 0.92 Si, 0.26 Ni, 23.8 Cr. Steel B – Subject to sigma formation; 0.13 C, 0.74 Mn, 0.71 Si, 4.1 Ni, 25.2 Cr, 1.47 Mo. (From same source as Fig 2)

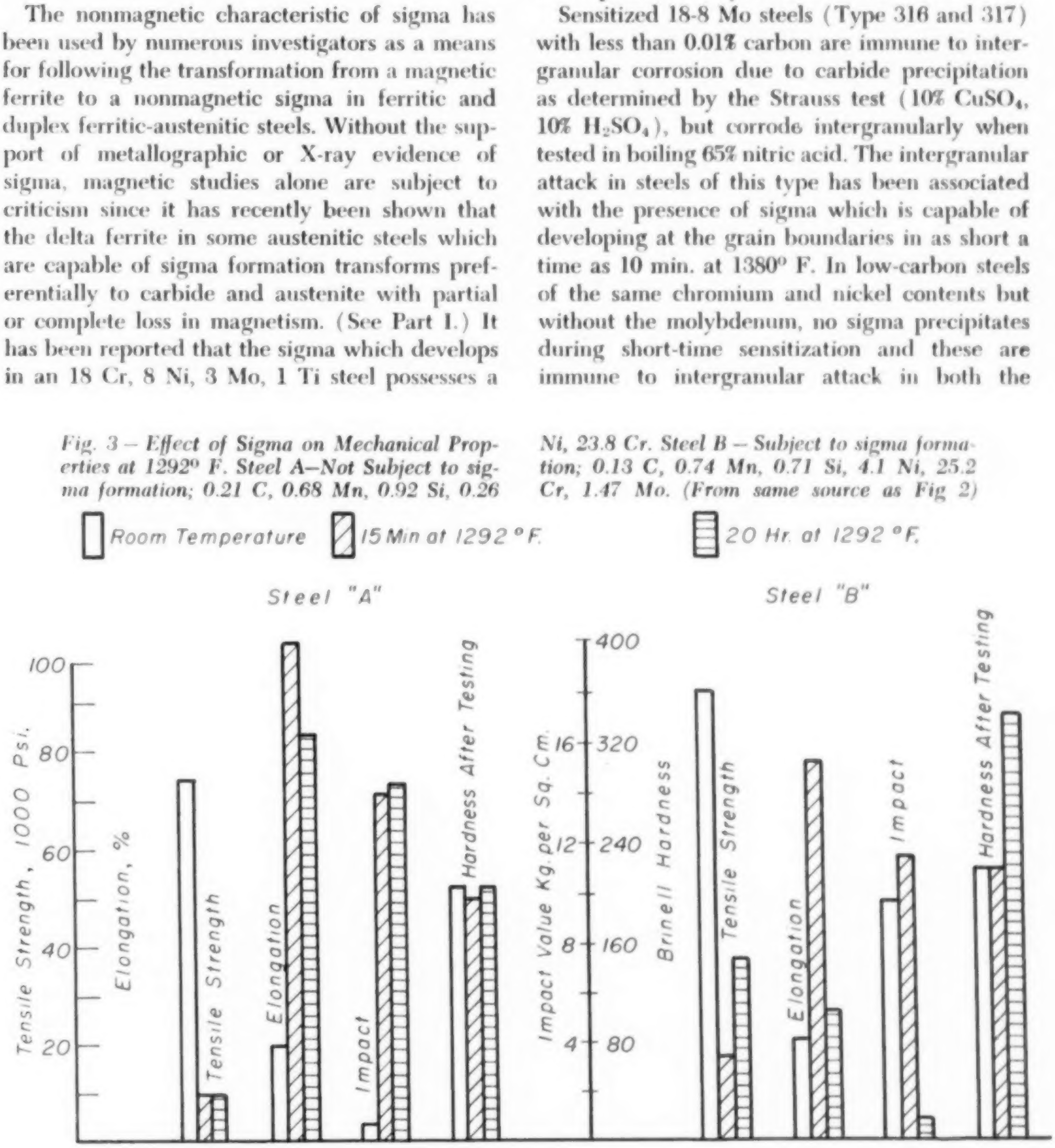


Fig. 4 – Low-Carbon Type 316 With Sigma at Grain Boundaries After the Following Treatments: (A) Annealed, Then Held 1 Hr. at 1400° F. (B) Annealed, Followed by 100 Hr. at 1400° F. (C) Annealed, Followed by 1 Hr. at 1200° F. (D) Annealed, Followed by 100 Hr. at 1200° F. Etchant, electrolytic sodium cyanide. 500 ×

Strauss and the nitric acid tests. A similar effect has been observed for Type 321 stabilized with titanium, the increased corrosion rate in nitric acid after sensitization being directly traceable to the presence of sigma.

Since both sigma phase and carbide precipitation occur in the same temperature range, it is often difficult to evaluate the individual effects of each. Intergranular susceptibility caused by sigma precipitation is observed only when tested in boiling nitric acid and not in the Strauss test, whereas intergranular susceptibility caused by carbide precipitation can be detected by both tests. We, in the Allegheny Ludlum Research Laboratory, have observed this effect of testing solution in a study of the corrosion resistance of low-carbon 18-8 Mo steels (Type 316 L). We have also found that the presence of sigma alone does not mean that the corrosion resistance of this steel will be impaired, but that the time of holding at the sigma formation temperature and perhaps the distribution of the sigma phase are of importance.

This conclusion may be deduced by correlating the data in Table I with the micrographs in Fig. 4 which show the effect of sensitizing treatment on the microstructure of a steel containing 0.024% C, 18.79% Cr, 11.68% Ni, 2.78% Mo and 0.045% N_2. The precipitate shown in Fig. 4 was identified as sigma by X-ray analysis of extracted residues. After 1 hr. at 1400° F. the corrosion rate is more than four times as great as in the annealed condition, but after 100 hr. at 1400° F. the rate has decreased to a low value in spite of a much greater quantity of sigma. A similar effect occurs during carbide precipitation in steels of higher carbon content, and the most common explanation is that diffusion of chromium after longer times succeeds in destroying chromium-depleted areas and corrosion resistance is restored. After 1 hr. at 1200° F. the corrosion rate is very high (although no precipitate can be observed in the microstructure) and increases with time such

that disintegration occurs after either 8 or 100 hr. at temperature.

Even 100 hr. at 1200° F. is not sufficient time to cause coalescence of the sigma.

None of the sensitized samples of this steel failed the Strauss test, which they most assuredly would have done had the high nitric rates been due to carbide precipitation. The importance of the distribution and size of sigma particles on the corrosion resistance of Type 347 is reported in the work of R. Franks and co-workers ("The Effect of Molybdenum and Columbium on the Structure, Physical Properties and Corrosion Resistance of Austenitic Stainless Steels", by R. Franks, W. O. Binder and C. R. Bishop; *Transactions* ⊕, Vol. 29, 1941, P. 35), who found that large sigma particles had a negligible effect on corrosion resistance to nitric acid whereas well-dispersed, fine particles were detrimental.

According to available evidence, the test in 65% nitric acid is the best for evaluating the effect of sigma on corrosion resistance. It has been suggested that nitric acid does not attack the sigma but attacks areas adjacent to it which are deficient in chromium. If this is true, the extent of depletion due to sigma formation should not be as severe as with carbide precipitation; sigma is an iron-rich as well as a chromium-rich phase and would leave a greater ratio of chromium atoms to iron atoms remaining in solution in adjacent areas than would carbides of the $Cr_{23}C_6$ type which are 94% chromium. This would account for the need of a more severely corrosive solution to show the effects of sigma than of carbides. Electrode potential measurements of compacted austenite and sigma residues in sodium chloride and hydrochloric acid solutions indicate that a chromium depletion mechanism may be operative in the attack of steels containing sigma. In these measurements sigma had a greater tendency to become passive and had a more noble potential than the austenite in equilibrium with it.

Table I – Effect of Sensitizing on Corrosion of Type 316L* in Boiling 65% Nitric Acid

Sensitizing Treatment	Corrosion Rate In. per Month
Annealed	0.0012
Annealed + 1 hr. at 1400° F.	0.0055
Annealed + 100 hr. at 1400° F.	0.0015
Annealed + 1 hr. at 1200° F.	0.0450
Annealed + 8 hr. at 1200° F.	Disintegrated
Annealed + 100 hr. at 1200° F.	Disintegrated

*0.024% C, 18.79 Cr, 11.68 Ni, 2.78 Mo, 0.045% N_2

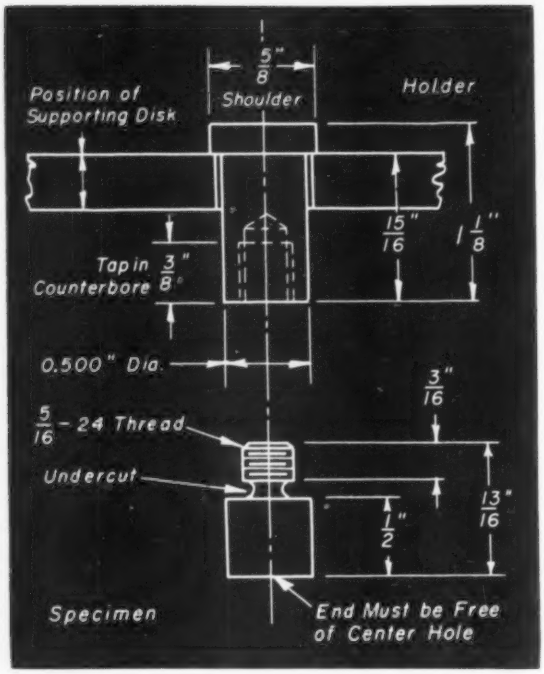
Effect of Sigma on Weldments

Reports on the effect of sigma on the mechanical properties of columbium-stabilized weldments in austenitic stainless steels disclose ductility in the as-welded condition to be greatest (above 30%) when the ferrite content of the weld is between 3 and 8% and no sigma is present. Ductility can decrease to 10% with as little as 5% sigma in the ferrite, which can transform either by the heat from subsequent weld layers or by heating in the range of 1100 to 1600° F. Time-temperature relationships for the transformation reveal 78% of the ferrite to be convertible to sigma within 2 hr. at 1400° F.; however, this amount is reduced by annealing at 1900° F. after welding and prior to aging at 1400° F. For good ductility of a weld, a minimum of 4% ferrite is desirable; but, if this ferrite is converted to sigma during welding or by subsequent heat treatment, both the ductility and corrosion resistance may be impaired.

The corrosion resistance in nitric acid and sulphuric acid-copper sulphate of weldments in Type 316, 316 L, 317 and 318 has been studied and effects similar to those described earlier in this article were observed: Sigma caused high corrosion rates in nitric acid which could be improved by agglomeration of the sigma through heat treatment. Variations in welding technique such as thin and thick weld layers and peening influence ductility only insofar as they affect the amount of sigma produced by heat treatment.

Summary – The magnitude of the effect which sigma may have on the mechanical and corrosion properties of stainless steels is greatly dependent not only upon the amount present but also on the particle size and distribution. In general, sigma increases the notch-sensitivity of all stainless steels and the impact strength is a more sensitive indicator of its presence than any other mechanical property. When sigma envelopes grain boundaries, the ductility at room temperature is greatly reduced and the resistance to attack in nitric acid is impaired. The effect of sigma on ductility at elevated temperatures is not so pronounced as at room temperature, a condition which often permits the use of sigma-containing steels at elevated temperatures. Well-dispersed sigma may increase tensile strength, but it has not yet been possible to use this property in high-temperature alloys because of other undesirable properties generally associated with its presence. ⊕

Fig. 1 – Exploded View of Specimen and Holder



Corrosion of Pump Parts

*By EDWARD H. HUSS**

Selection of constructional metals for pumping such liquids as chemicals, foods, mine waters, brines, is guided by determining the weight loss during 48-hr. exposure to moving solution, closely controlled as to temperature and aeration.

Selection of materials for chemical equipment is a difficult and sometimes disputatious task. In the absence of standard tests for the corrosion rates of various metals and alloys, the manufacturer is obliged to devise a method adaptable to his particular needs – for rotary pumps in the case of Viking Pump Co. Since high performance of a rotary pump is dependent on clearances between mating parts, corrosion is a prime consideration. Rotary pumps are daily called upon to handle a multitude of liquids, some corrosive to one metal or alloy yet inert to others; therefore the need for an accurate test procedure for the metals of construction becomes of prime importance. We have devised a test method that gives a good indication of how pumps will act during service, and it is thought that the simple equipment and method may interest others faced with similar problems.

In our test, several important variables in the test liquid – such as concentration, temperature, impurity content, and aeration – are taken into account. One major factor that cannot be included in this type of test is the velocity with which the liquid passes over the pump's moving parts. If the velocity is high the liquid will erode

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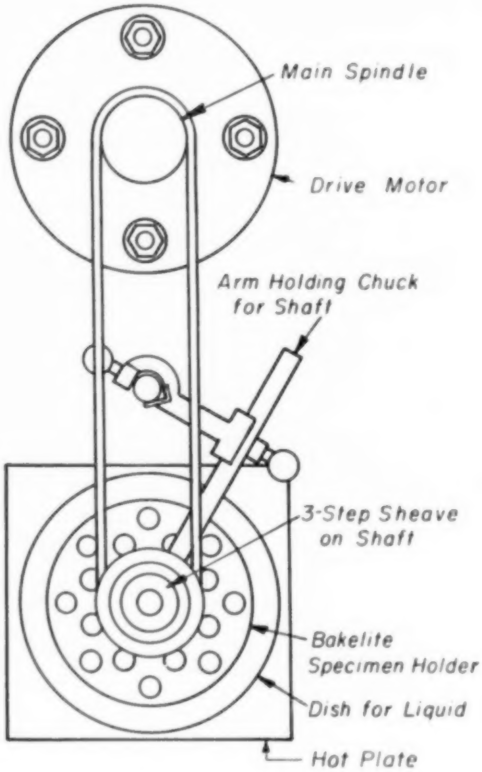

Fig. 2—Plan of Equipment

or wash away any protective films present on the metals. Since the velocity of the liquid varies from place to place inside the pump, this velocity factor is extremely difficult to appraise in the laboratory.

Test pieces can best be described by reference to the illustrations. Figure 1 illustrates the test specimens and holder used in the Viking laboratory. The specimen is a cylinder approximately ½ in. in diameter and length; it has a threaded end that is screwed into the holder. Since dissimilar metals are frequently responsible for failure of chemical equipment through electrolytic action, the specimen and holder are interchangeable — that is, a specimen of one metal can be screwed into a specimen holder of a different metal, so any feasible combination may be used. Electrolytic action can be noted during the test and recorded if the difference in potentials of the metals accelerates the nature or rate of chemical attack.

The specimen prior to a corrosion test is prepared as follows:

1. The specimen is ground to a true cylindrical shape and its end ground with a 60-grade grit grinding wheel.

2. Diameter and length are measured with a 0.0001-in. indicating micrometer.

3. The specimen is immersed in clean ethyl or methyl alcohol and washed clean of fingerprints and foreign matter which may be present, then removed from the alcohol and dried.

4. Specimens are then heated to 90° F. for 15 min. in a drying oven, and cooled in air.

5. Specimens are weighed to the nearest 0.0001-g. Measurements, weight, and specimen area are recorded.

6. Finally, each specimen is screwed tight into its holder. Since there is no clearance at the shoulder, the *area* of the test specimen is figured as the cylindrical area plus the area of the circular end.

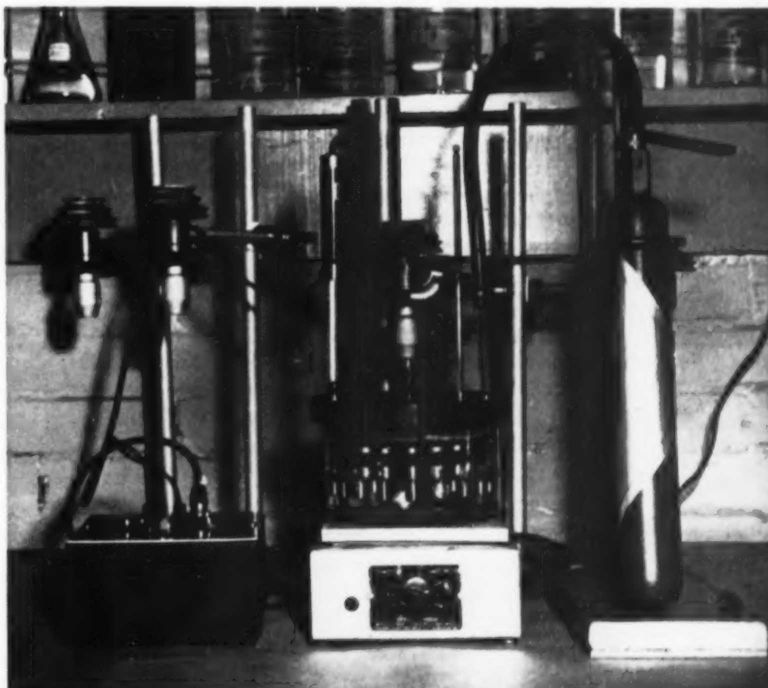

Fig. 3—Photograph of Set-Up. Corrosion equipment in center, electronic relay and control box at left, gas cylinder for aeration of solution at right

Test Equipment

Figure 2 is a plan sketch of the equipment and Fig. 3 a photograph of the set-up.

The various test specimens and holders for exposure to a given solution are placed in a nonconductive bakelite retainer which is a ⅜-in. horizontal disk, 4⅜ in. diameter, to whose center is attached a ½-in. vertical stem. A number of holes 0.53 in. diameter are drilled through this disk, into which the specimens (in their holders) can be slipped. Eight of these holes are equally spaced around a 2⅛-in. circle and 14 around a 3⅞-in. circle. The receptacle for the test liquid is a 500-ml. Pyrex crystallizing dish and it contains enough solution to cover the test piece and about ¼ in. of its holder, protruding below the supporting disk (see Fig. 1). The Pyrex dish is covered with a wooden plate which is provided with holes for thermoregulator, thermometer and gas dispersion tube.

The stem of the bakelite retainer is then inserted in the vertical drill chuck, as shown in Fig. 3. An 1800-rpm. motor, V-belt drive, and gear reducer provide the power. The motor is geared to drive the specimens in the outer ring at 2.4 in. per sec. through the test liquid.

The regulated temperature of the liquid during the test is the same as the intended temperature in service, and is kept within plus or minus 0.1° of the pumping temperature by the thermoregulator and electronic relay. If the test liquid is to be aerated, air or oxygen from a nearby cylinder is dispersed into the solution through a perforated Pyrex tube.

Duration of the test is usually 48 hr., but if the corrosion is unusually severe it may be shortened at the option of the operator.

Upon completion of the run, the bakelite retainer is removed from the test liquid, the specimens and holders removed from their individual niches and closely examined for pitting, preferential corrosion at water line, or evidences of galvanic action. They are unscrewed from their holders, washed in distilled water for several minutes, then immersed in clean ethyl or methyl alcohol to remove any residue or test liquid, and finally dried at 100° F. for 15 min. in an electric oven. The specimens are then cooled and reweighed, and the difference in weight recorded. The rate of corrosion is measured in inches penetration per year (ipy.) and may be computed by the formula

$$\text{ipy.} = \frac{365W}{ndA}$$

where W is weight loss in grams
n the number of days duration of test
d the density of the metal in mg. per cu. in.
and A the exposed area (side + bottom) in sq. in.

If electrolytic action is noticed during the test, a direct-current milliameter or microammeter is used to determine the amount of current present. As noted above, any visual changes in the test specimen such as attack at the liquid-air junction, rusting of the specimen holders, or pitting are recorded.

A typical report would be one on the corrosive action of 20% ammonium nitrate solution at room temperature. Aeration of liquid was uncontrolled; specimens moved at 1.28 in. per sec. for 48 hr. Holders were of stainless steel. Results follow:

K-Monel	0.0188 ipy.
Ni-Resist #1	0.0253*
Ni-Resist #2	0.0216*
Ni-Resist #4	0.0055*
Stainless 440c	0.0011
Stainless 410	0.0015
Stainless 316	0.0017
Stainless 316 hardened	0.0018
Nickel silver B-10	0.0411†
White bearing metal B-9	0.0680†
Hi-lead bearing metal B-8	0.0880†
Leaded red brass B-5	0.0863†
Tin bronze B-4	0.0726†
Carbon steel 1040	0.2040
Case hardened 8620	0.3250
Sorbo-Mat III E cast iron	0.2720
Experimental cast iron	0.2050

*Badly rust stained
†Severe intergranular attack

Since severe evidence of electrolytic corrosion was noted, it was evident that the parts of the pump in contact with the liquid should be made of a single metal. A new test was then made with each sample in a holder of the same metal.

Summary

As was formerly stated at the outset, in the absence of a standard corrosion test, the described method has proved most satisfactory in our laboratory, and the resulting recommendations for materials of construction have proved to be very helpful to our customers. A partial list of liquids that have been tested by the above method includes concentrated nitric acid, 10% nitric acid, 10% chromic acid, various fatty acids, slurries of commercial fertilizers, paints, cutting oils, boiling starch solutions, cleaning solutions, stearic acid, molasses, 10% acetic acid, fumigants and disinfectants, 20% ammonium nitrate, 30% cupric chloride, many different mine waters, and cooked pumpkin pulp.

Improved Hardening Technique

*By EDUARD M. H. LIPS and H. VAN ZUILEN**

Unusually high yield and creep strengths, associated with excellent ductility, are acquired by wire or strip "cold worked" in the austenitic state (below the nose of the TTT-curve) and then transformed during air cooling.

To the traditional quench-and-temper process for hardening and strengthening steel, scientific research, through its insight into the metallurgical changes involved, has added at least three important hardening processes during the past 20 years – namely, isothermal hardening, martempering and austempering. Each of these (and to them may be added the patenting process for wire) gives a characteristic microstructure and set of mechanical properties.

Within recent years we have done some work in the Philips' laboratories which has resulted, we believe, in a new method. It seems particularly suitable for use in manufacturing wire or strip. Not only do good mechanical properties result, but these properties are usually better than attained by conventional methods.

The new method of steel hardening differs from usual ones in that the formation of martensite or of bainite takes place from a deformed austenitic structure. The work is done at a heat below the recrystallization temperature and therefore may be called "cold working", although the metal is by no means "cold" to the touch.

In our new process the steel is first brought into the metastable austenitic condition† wherein it is worked to its final shape. Subsequent transformation of the metastable "cold worked" austenite into the bainite or martensitic microstructure results in a steel with outstanding mechanical properties. These properties depend on the *degree* of "cold work" prior to the transformation of the austenitic structure. Therefore, deformation should be carried out below the recrystallization temperature and should be almost completed when the transformation of the austenite begins.

Satisfactory results are therefore to be expected with the new method if the steel has such a

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†Editor's Footnote – As by austenitizing and then quickly quenching to below the "nose" of the TTT-curve where austenite has a comparatively long incubation period.

TTT-diagram that, at temperatures below its recrystallization temperature, the metastable austenite has a relatively long life, and that these temperatures can be reached without appreciable formation of ferrite.

If conditions are such that decomposition of the metastable austenite leads to a ferritic-bainitic structure, the deformation may be continued even during the austenite transformation.

Two examples will show the result of the new hardening method as applied to the manufacture of strip and wire.

Strip – If a chromium-nickel steel (4.5% Ni, 1.5% Cr, 0.35% C) is hardened in the conventional way the following properties are obtained:

Yield point	295,000 psi.
Rockwell hardness	C-56.5
Elongation	2%
Reduction of area	5%

The characteristics cited below are obtained on the same steel after rolling in the austenitic state according to the new method:

Yield point	400,000 psi.
Rockwell hardness	C-58
Elongation	12%
Reduction of area	42%

This strip has outstanding spring qualities. Its ductility is quite unusual for this high hardness.

Wire of high creep strength is another striking product of this improved hardening method. The example is a typical music wire of plain carbon steel containing 0.9% carbon.

After austenitizing, the wire is drawn through dies while immersed in a suitable hot liquid, the temperature of which is chosen in accordance with the new hardening method.

After cooling, the steel wire exhibits mechanical properties which have in the past been approached only by the comparatively complex process of patenting followed by cold drawing.

Eutectoid carbon steel wire merely drawn and cooled – that is to say, hardened by the new method – showed a creep strength of about 310,000 psi. as measured according to the normal European practice for prestressed concrete wire. This figure compares with 220,000 psi. for steel ordinarily used in prestressed concrete.

Conclusion – The improved hardening method opens the way to important developments, especially in the manufacture of wire and strip for prestressed concrete, strip for tools, cutlery blades and springs, and wire for needles.

Critical Points . . .

By the Editor...

A Mill for Magnesium Sheet

A VISITOR to Dow's new rolling mill for magnesium plate and sheet is first struck by its roominess – it being located in an oversized war-baby intended for tank armor. Only the buildings were retained; the equipment is newly installed and a two or three-fold expansion would not cramp it for space. Notable are three continuous casting machines for round billets up to 18½-in. diameter and slabs up to 11 x 42 in. in cross section. At each station, six gas-fired melting pots are set in the floor, fan-wise, and molten metal (checked for analysis by direct-reading spectroscope) is pumped to the casting machine through a 1-in. pipe. The mold is a water-cooled collar, the downward passage of solidified metal is controlled through pinch rolls, and its lower end is sawed off periodically to billet or ingot length. Thin disks also are frequently cut and fractured to examine the grain size. All this is in a deep pit below floor level. Speed of casting (pumping and pinch rolls) is controlled electrically by maintaining the level of the liquid puddle constant.

The nominal remelt capacity is 50,000,000

lb. of rolling and extrusion ingots per year.

To avoid perpetuating surface defects, round ingots are turned prior to heating for extrusion; slabs are also milled about ⅛-in. on sides and edges before rolling. (Machining of magnesium is very, very easy and fast, you will recall.) A four-high, reversing plate mill with conventional tables, manipulators and other auxiliaries, but with the addition of huge 42-in. vertical cylinders for edge rolling, will convert a 10 x 40 x 76-in. slab, weighing upwards of 2000 lb. to a ⅛-in. plate 76 in. wide and 136 ft. long in 21 passes. Time required is about 5 min., during which the metal cools from its original 800° to 600° F. Thin plate is coiled; further rolling to thinner sheet is done on single-pass mills; the coils are heated to 750° F. prior to each pass. Warm magnesium can take a big wallop in such a roll stand.

The present mill can ship about 16,000,000 lb. a year of sheet 0.032-in. gage; its capacity for heavy gages and plate is several times this.

Other interesting varients from steel or brass mills are the cavernous reheating furnaces – "ovens" they might more properly be called – necessary for uniformly heating considerable masses of metal to moderate temperature without overheating in any place. Another is the almost universal use of saws rather than shears for cutting and trimming – easy machinability again! Also there's no scale. It's strange, too, to see metal being manhandled with asbestos mitts.

This new mill at Madison, Ill. (just over the Mississippi from St. Louis) was dedicated to Edwin O. Barstow, vice-president of Dow Chemical Co., on May 26, in fitting ceremonies. Responding to an invitation for remarks from a representative of the metals industry, the Editor of *Metal Progress* read the following:

"The opening of this fine, new rolling mill is a landmark in the history of magnesium metal. I do not need to remind this audience that its history in America begins with the development of the electrolytic cell by Dow Chemical Co.'s men headed by Dr. Barstow between 1916 and 1922. Sales amounted to 859 lb. in 1919. So you can see that magnesium is a very young metal indeed. The curve of its growth has some peaks and valleys, but it takes no prophet to say that peacetime uses of a metal depend on its ready availability in sheet, shapes and other mill products. The very existence of this mill is bound to stimulate commercial uses.

"Especially is this true in magnesium's utility as a structural metal. The world is on the move and not for long can even America with all its riches endure the luxury of pushing a 4000-lb. vehicle over a road with a 250-hp. engine. Efficiency in everything that moves on the surface or in the air will *demand* ever more effective use of the light metals in structure and power plant. Here is a field of future consumption almost without limits.

"Magnesium of course is not the only light metal. Aluminum is a constant competitor, and titanium – at least if you believe all you read – a new one. One advantage has magnesium however, which *no* other metal possesses – a truly inexhaustible bonanza in the mighty ocean. *Never* need the magnesium industry bother about its raw material. It can rest secure while all the other metals – even iron – must worry about the steadily decreasing tenor of the ore supplies and face a continuing rise in costly extraction.

"I do not need to remind you that many of the heartbreaking setbacks surmounted by Dr. Barstow and his crew in the early days just 35 years ago were due to the chemical activity of the metal. While this property has caused much sales resistance from men who think of magnesium chiefly in terms of incendiaries and flash bulbs, its chemical activity will, I'm sure, be responsible for a steadily increasing and gratifying volume of sales. I refer to the fact that magnesium is the chemical element almost universally used to reduce the really new metals of the atomic age. In place of carbon which serves for iron, copper and the other old metals, we have magnesium for thorium and uranium, the heaviest metals, puissant in the field of power, both industrial and political!

"Also in the field of alloys and alloying metals: We know a little about the possibilities of six or eight metals like manganese, chromium and vanadium, but practically nothing about some forty metals in the periodic sequence – now rare, but frequently rare because nobody has used magnesium to reduce them – and the possibilities of these unknown metals as alloys for our old reliable iron and copper, and our new mainstays magnesium and aluminum, are beyond imagining.

"So in its own right as a noble metal and in its power to bring forth the genii of the other metals of tomorrow, magnesium has a future as limitless as the oceans from which it comes. And to some of you skeptics may I remark 'It's sooner than you think!' "

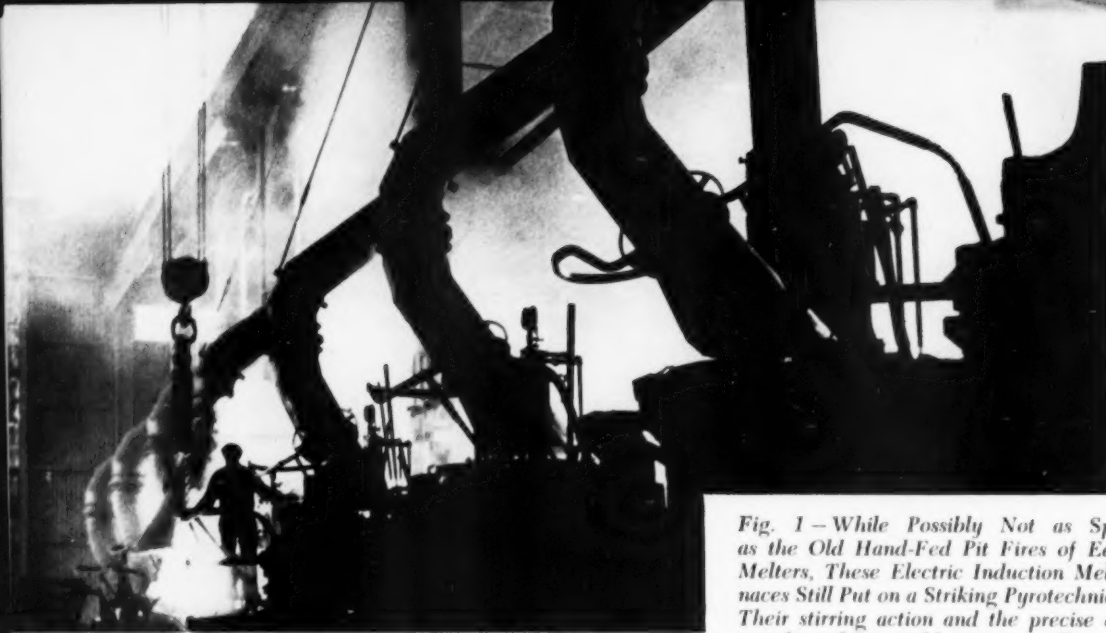


Fig. 1 – While Possibly Not as Spectacular as the Old Hand-Fed Pit Fires of Early Brass Melters, These Electric Induction Melting Furnaces Still Put on a Striking Pyrotechnic Display. Their stirring action and the precise control of metal analysis yield superior alloys in terms of strength and corrosion resisting qualities

Modern Trends in Brasses

*By ARTHUR H. ALLEN**

Eight metals are now commonly added to copper and zinc (the time-honored brass) to improve its engineering properties and resistance to several types of insidious corrosive attack. Silicon and aluminum especially are able to add strength and toughness.

EIGHTY-NINE years' experience at Bridgeport Brass Co. in development and production of copper-base alloys for metal fabricators could not help but result in a wealth of data leading to the more intelligent and profitable use of these materials. Principal brass, bronze and copper products – rod, wire, strip and tubing – have long been furnished by Bridgeport's Connecticut plants to the construction, air conditioning, electrical, chemical, automotive and public utility industries. In addition, the company operates its own fabricating division. For example, it is one of the largest producers of tire valves, and a project now under way is directed to the production of a new line of cooking utensils, to be formed from copper strip clad on both sides with stainless steel.

*Technical-Business Consultant, Cleveland

Innumerable specialties and "tailor-made" alloys have been incorporated into the Bridgeport line over the years, notably high-strength silicon bronzes, aluminum bronzes, phosphor bronzes and nickel-silvers. Development of specialized copper-base alloys calls for the most diligent research, including both field and laboratory studies, as well as close control of melting and rolling. Still a major objective of the brass and bronze industry is a thorough and systematic

evaluation of the effects of addition elements and the discovery of additions (titanium may be a new one) that will provide useful characteristics.

Effect of Common Additions

As a refresher for metallurgists who may have lost track, the following summary pinpoints the significant effects of eight common "additives":

Lead is added to brass in amounts ranging from 0.15% to 4% for improving machinability. Limitations are placed on the amount added because of harmful effects on ductility and hot and cold forgeability, as well as difficulties in dispersing this insoluble metal uniformly. The stirring action of the induction melting furnace, now used for all alloys at Bridgeport, considerably improves the lead dispersion.

Tin is added in amounts up to 2% for better strength, corrosion resistance and appearance. Examples are admiralty metal condenser tubes with 70% Cu, 1% Sn, remainder Zn; and naval brass with 60% Cu, 0.75% Sn, remainder Zn. Tin added to the high Cu-Zn alloys increases strength and modifies the color, making this alloy combination popular with the jewelry trade.

Fig. 2 – One of the Most Important Tools Aiding Control of Melt Quality Is the Direct-Reading Spectrometer Which Indicates the Metallic Contents in Alloys at a Rapid Rate so Immediate Adjustments May Be Made if Necessary. Equipment is housed in an air-conditioned room supported on extra-rugged foundations

Aluminum is added to brass to improve resistance to impingement corrosion from turbulent water containing entrapped air and flowing at high velocity. Aluminum brass condenser tubes analyze about 76% Cu, 2% Al, remainder Zn. The element also increases strength and often is one of the minor constituents of manganese bronze (a 60-40 brass with small amounts of Mn, Fe, Sn and Al).

Silicon – a small percentage of silicon in brass lowers thermal and electrical conductivity to make it more suitable for spot welding; it also reduces fuming of bronze welding rod. Silicon in amounts up to 3% in copper increases strength and toughness, while silicon in aluminum bronze improves strength, corrosion resistance and machinability. As in brass, silicon affects the alpha-beta phase boundary relationship; thus, a normal alpha structure may be thrown into the alpha-plus-beta structure with correspondingly better hot working properties.

Manganese decreases electrical and thermal conductivity in brasses and bronzes to a point where they can be resistance or spot welded.

Iron increases the strength and hardness of brass, and is sometimes added to Muntz metal (62-38 Cu-Zn). It retards grain growth during annealing. However, specifications for brass strip for cupping or deep drawing limit the permissible content.

Nickel is added to Cu-Zn alloys to produce "nickel-silver" alloys. Addition of nickel whitens

brass until it becomes silvery in color, and its strength increases with the nickel. The alloy with 18% Ni is commonly used as a base for silver-plated hollow ware. The element greatly lowers electrical conductivity of copper alloys and adapts them to parts needing high resistance.

Arsenic is commonly added to inhibit dezincification of brasses with more than 20% Zn, used for condenser tubes in both fresh and salt water.

Summary of Useful Properties

Basic properties of the brasses are familiar to most engineers. They encompass such things as good corrosion resistance, wide range of strength and hardness, high heat and electrical conductivity, resistance to fatigue, abrasion and wear, good spring qualities, pleasing color, nonmagnetic characteristics, ease of finishing, plating and lacquering, ease of cold and hot working, good machinability, easy brazing, soldering and welding. Some uses require more emphasis on one quality than on another and it is in this realm that the brass producer, as well as the consumer, must consider and weigh carefully the engineering applications of the material.

In general, physical properties of the alloy depend upon its state – that is, whether it is cast, rolled, extruded, drawn or annealed. Ductility, springiness, toughness, strength and stiffness are dependent upon annealing or the amount of reduction by cold rolling or drawing following the last anneal. Machinability, corrosion resistance, hot and cold workability are controlled largely by modifying proportions of copper and zinc and by the additions of small percentages of the elements just reviewed.

As a "manufactured" alloy, brass thus is dependent to a high degree on quality control in melting and rolling operations. One of the most important advances in improving uniformity and quality of present-day mill products was made about twenty-five years ago in shifting from the old-time hand-fed pit fires to induction melting (Fig. 1). All Bridgeport melting has been done in induction furnaces for years, some of the largest units having a capacity of 2000 lb. Frequent laboratory checks on melt analyses use both chemical methods and the direct-reading spectrometer (Fig. 2). The latter has proved especially valuable for fast and accurate determination of alloy content and impurities just prior to casting. As many as 12 different metallic elements may be "clocked" within a minute or so on the spectrometer.

Laboratory control extends all the way from sampling of incoming raw materials, through melting, rolling and annealing operations to the finished product. It does not stop there, but moves on into the field to probe the causes of service failures and to suggest remedies.

The Fight Against Corrosion

Corrosion naturally is one of the principal problems to be assessed in this area (as in almost all materials). It takes many forms, such as:

Impingement corrosion, from a fast-moving stream of water or other liquid or gas which removes the thin protective film from the surface and thereby gains access to the metal beneath.

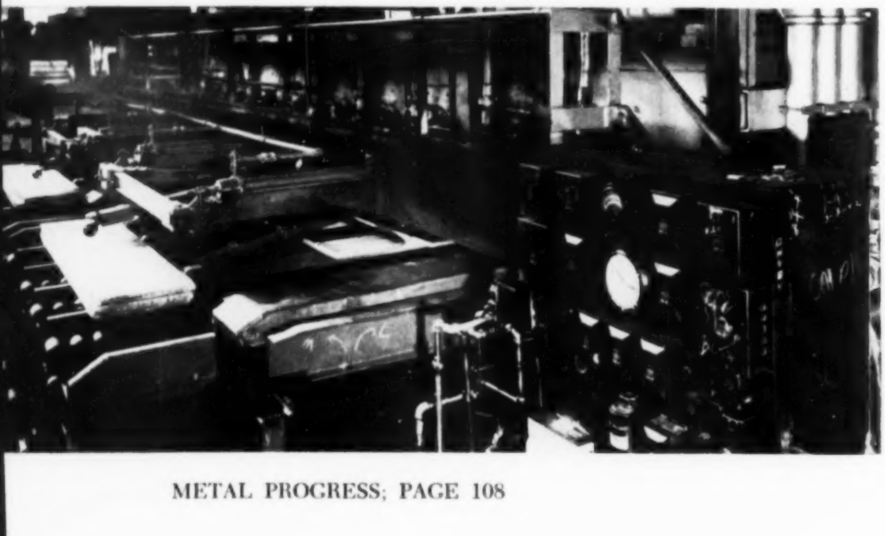
Dezincification occurs under prolonged exposure to certain moist or wet conditions in alloys containing less than 85% copper and generally in the absence of an inhibitor.

Galvanic corrosion results from contact of dissimilar metals in water containing soluble salts.

Fatigue corrosion arises from prolonged periods of vibration in service.

Heat corrosion is often caused by too severe grinding or rough handling of brass while still in the brittle range after annealing.

Fig. 3 – As Alloy Slabs Proceed Through the Hot Mills, They Must Be Frequently Annealed. Typical is this walking-beam furnace which handles slabs automatically



Stress-Corrosion or season cracking – once a mysterious disease that occasionally struck brass articles after many years of immunity.

Stress-Corrosion Cracking

The mechanisms of most of these are now fairly well understood, with the possible exception of stress-corrosion which lately has been the subject of intensive study at the Bridgeport laboratories. This form of cracking (not necessarily intercrystalline, since the fine cracks characterizing it frequently are observed directly across metal grains) may develop in many materials other than copper alloys under external or applied stresses much below their rated strengths and in many diverse types of corrosive media, even in industrial atmospheres. Carbon steel is so affected by certain caustic solutions, stainless steel by acid chlorides, aluminum and magnesium by sea water, different plastics by various solvents, copper alloys by ammonia, and rubber by oxidation.

Conditions which are known to contribute to failures from stress-corrosion cracking in brass and copperbase alloys are the following:

1. Existence of high tensile stress, either locked-up or internal stress, as a result of cold work, rapid cooling or quenching, with or without additions from applied stresses such as occur in tightly screwed bolts and hanger rods.

2. Presence of moist ammonia even in traces so slight that they cannot be detected by sense of smell or by oxygen.

3. Air or oxygen. Where minute amounts of ammonia or low internal stresses are involved, a long period of time may be needed before cracking develops. On the other hand, given the proper atmosphere, it is possible to detect cracks in annealed yellow brass under 25,000 psi. applied stress in as little as 1 hr.

4. Susceptibility of the material, as related to composition. Higher copper brasses, for example, are less susceptible to the phenomenon.

Stress-corrosion failures can be prevented by avoiding the above hazards. Cold work stresses can be relieved by low-temperature anneals (Fig. 4) while the effects of atmosphere must be circumvented by proper choice of alloy analysis.

High-Strength Bronzes

Probably the fastest growing family of copperbase alloys, even though their roots date back 25 years or more, is the silicon bronze and silicon-aluminum bronze group, which Bridgeport Brass identifies under the proprietary term "Duronze".

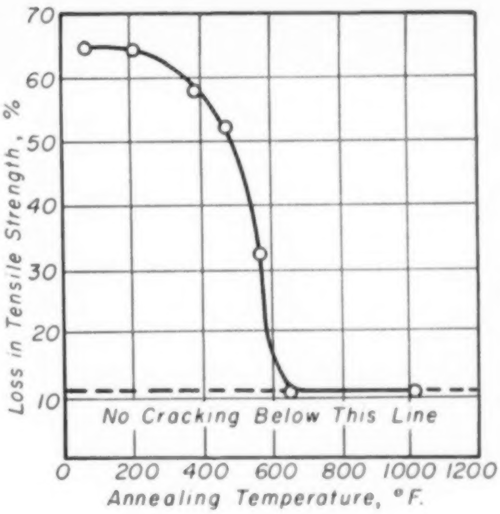


Fig. 4 – Proper Stress-Relief Can Prevent Stress-Corrosion Cracking. Material is hard, leaded, yellow brass tubing subjected to alternate immersion in 50% solution of 15 N NH_4OH

They were originally five in number, with the approximate compositions shown in Table I on the following page.

Because these alloys all contain high copper, they are superior to 60-40 brass in respect to strength and corrosion resistance. All have high fatigue resistance and, of course, are nonmagnetic. Principal points of difference are workability, machinability and hardness. Specific characteristics are as follows:

Duronze I – High strength resulting from cold working . . . exceptionally malleable even when hard drawn . . . smaller sizes of cold headed rolled-thread bolts average over 100,000 psi. tensile strength.

Duronze II – Strength and toughness of mild steel plus corrosion resistance of fine bronze . . . hot rolled sheets suitable for welded fabrication of tanks and flues . . . cold rolled strip has excellent spring qualities.

Duronze III – Exceptionally strong and hard, yet free machining . . . difficult to cold work but hot forges well . . . Especially suited to high-strength forgings and screw machine items.

Duronze IV – Recommended as one of the best condenser tube alloys available . . . resists impingement and other types of corrosion from polluted, brackish waters.

Duronze V – Supplied in hard drawn condition . . . especially developed for cold heading of high-strength bolts.

Table I – Compositions of Duronze Alloys

Type*	Composition, %			A.S.T.M. Equivalents
	Cu	Si	Others	
Duronze I (Silicon bronze 813)	97.6	1.0	1.4 Sn	B98-45(B), B99-45(B), B97-44(B)
Duronze II (Silicon bronze 632)	97	3		B98-45(A), B97-44(A), B100-44(B), B96-42
Duronze III (No. 707)	91	2	As 7 Al	B150-46T, B124-45 (No. 11)
Duronze IV (No. 53)	94.25	..	5.5 Al, 0.25 As	B111-45
Duronze V (Silicon bronze 609)	98	2		B98-45(B), B11-44(B)

*In the process of evolution, Alloys I, II and V have become dissociated from the name Duronze in favor of the numbered silicon bronze alloys indicated. Currently, Duronze is confined largely to Types III and IV (No. 707 and No. 53).

An important characteristic of Alloy III is its lower specific gravity; because of its aluminum content it is about 10% lighter than comparable high-strength silicon bronzes. Many sizes of rod in this grade are available with tensile strength of 90,000 to 95,000 psi. Further, its high corrosion resistance peculiarly suits it for equipment for sewage disposal plants, pulp and paper mills, breweries, salt refining, marine hardware, pickling tanks and valve bodies for water, oil, steam and gases.

Alloy I was developed originally in answer to demands for a high-strength material for catenary construction in the electric railway field. There are some installations still operating in this country after a quarter-century with no record of failures.

Combination Tubing

Another Bridgeport specialty is duplex tubing, produced by cold drawing tubing of one material over another that is slightly smaller in diameter. The method insures a snug fit before drawing and good mechanical contact after reduction to size. Duplex tubing is well suited to condenser and heat exchanger tubes wherever a dual corrosion problem is involved. More than 100 combinations of metals are available, with one either inside or outside the other, depending upon necesssity. These combinations include brass, copper, cupronickel, aluminum and silicon bronzes, Muntz metal, aluminum, lead, Monel metal, nickel, carbon steels, stainless steels, tin and tin alloys.

Where galvanic corrosion of tube ends is of concern, the outside component of the duplex tubing is cut back and replaced with a sleeve of the same composition as the inside layer. Another special treatment is "end annealing" to facilitate rolling in. In the thinner gages of the available range (0.049 to 0.375 in.) the wall thickness is generally equally divided between the two components; in heavier gages, the wall thickness of one tube may be only one-third to one-fifth of the total wall thickness.

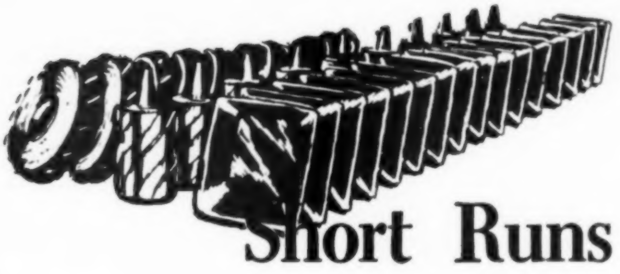
Other diversifications include a new high-speed mill for shaping and induction welding aluminum tubing at speeds up to 120 ft. per min. (*Metal Progress*, February 1954, p. 65), and acquisition by lease of the U.S. Air Force heavy press and extrusion plant at Adrian, Mich. The latter has been in operation for several years under different managements, turning out aircraft pressings and extrusions in aluminum and magnesium. Its output will be extended to cover commercial extruded and pressed shapes, rods, wire and tubing of various light metal alloys. Finally, a new tube drawing mill, now under construction at Bridgeport, will cut costs appreciably.

Summary

"Tailor-made" copper-base alloys are available to meet a multitude of service conditions involving complex corrosion conditions. Exploration of their potentialities should go beyond initial cost and take into account such factors as resistance to the different forms of corrosion, workability, strength and hardness range, as well as expected service life.

Consultation with materials suppliers who have had long experience in developing and testing special alloys, as well as intimate knowledge of the case histories covering field performance, can go far toward overcoming design errors and avoiding the dangers inherent in "engineering at a price".

Superiority of the modern silicon bronze and silicon-aluminum bronze alloys for many applications, both outdoor and indoor, where corrosion is inevitable, suggests that careful evaluation of their strength and corrosion resistance is certain to show that their selection will give profitable service.



Short Runs...

Specifications

IN THIS DAY of proposed interchange of engineering and technical information, the following report from Hal C. Tyree, materials engineer at the Electro-Motive Div. of General Motors Corp., La Grange, Ill., is both timely and interesting:

If the request on a work order coming to your desk stated, "Make this part from Z 15 CN 18", you probably would not immediately pencil "A.I.S.I. 302" in the corner of the paper, but the two specifications are almost identical.

The very logical Frenchman, in a system monitored by the Chambre Syndicale des Producteurs d'Aciers Fins et Speciaux, has developed a set of steel specifications adaptable to anything from a "steel" designation, with no other qualification chemically or physically, to a complicated tool-steel with narrow chemical requirements.

"Steel", the material mentioned above, is designated as ADx and has no chemical or physical requirements.

"A" steels are those which must meet physical requirements. A typical specification is A 37 h; the 37 indicates minimum tensile strength of 37 kg. per sq.mm. (53,000 psi.); the suffix h denotes the only chemical restriction; this being phosphorus and sulphur limitation. There are gradations from "a" (0.09% phosphorus, 0.065% sulphur) to "m" (0.02% P, 0.035% S).

"C" steels have definite carbon limits; thus, C 35 d restricts the carbon content to an average of 0.35%. An x prefix means a special-purpose material with a narrow carbon range or other modification.

Designations for low-alloy steels (less than 5% alloy) indicate carbon content, principal alloying elements, and alloy content of at least the major alloying element. For example, 16 NCD 13 h is a 0.16% carbon steel containing 3.25 nickel, N, as well as chromium C and molybdenum D. The nickel content is multiplied by 4 to obtain the number 13 in the specification. The content of some alloying elements such as aluminum and molybdenum is multiplied by 10. The multiplication system is used to afford a means of distinguishing between similar alloys. Were it not for this means of separation, a 0.60% nickel steel and a 1.5% nickel steel, for instance, would have the same designation.

High-alloy steels (over 5% alloy) dispense with this elaborate multiplying system and are always preceded by Z. Z 15 CN 18 is therefore an 18-8 steel with 0.15% C; *c'est practique, n'est-ce pas?*

Metallography

BETTER definition of microconstituents in tool and die steels is obtained from a polishing technique incorporating the use of diamond abrasives, according to a report from Birger L. Johnson, metallurgist, Latrobe Steel Co.

The mounted specimen is first prepared in the usual manner on abrasive papers, normally through 3/0 emery paper, and then is polished with U.S. grade No. 3 diamond (1 to 5 microns particle size). However, the polishing of particularly abrasion resistant steels and sintered carbides is done best by using No. 320, 400, 500 and 600 silicon carbide papers instead of emery, and then polishing successively with No. 15 (8 to 22-micron) and No. 3 diamond. Polishing with diamond abrasives smaller than No. 3 is not beneficial unless the wet lapping is omitted; in such instances the final polish is with No. 1/2 (0 to 1-micron) diamond.

Polishing is done by hand on a lap of several thicknesses of bond paper backed by plate glass. The diamond abrasive, available in paste form in flexible metal tubes and plunger-type dispensers, is applied in very small amounts to the paper. During the polishing operation, moderate pressure is applied to the specimen as it is rubbed back and forth in even strokes over the paper. Because the diamond abrasive has a

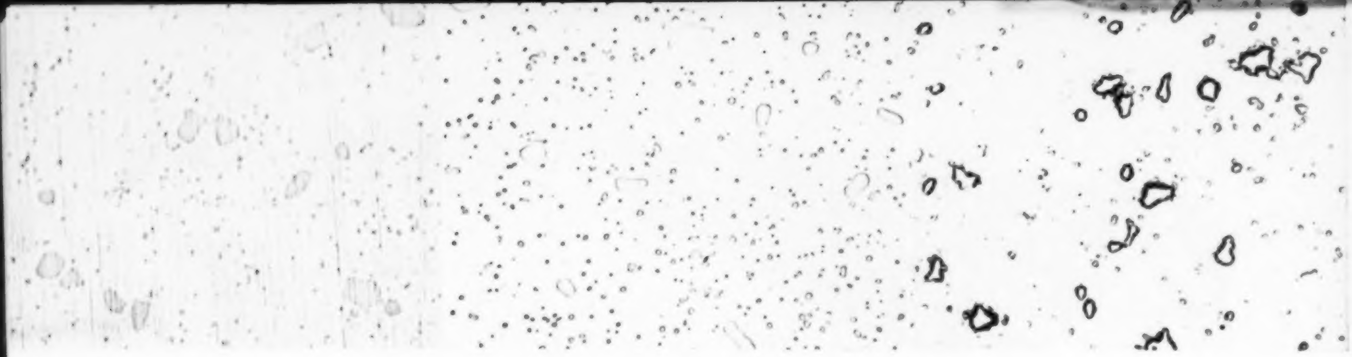


Fig. 1 – High-Speed Toolsteel (6% W, 6% Mo, 4% Cr, 3% V, 1.15% C) Fully Hardened to Rockwell C-65, Showing Effect After Various Polishing Procedures; Unetched, 500×. (Left) Polished with U.S. grade No. 3 diamond abrasive. (Center) Same as preceding but after polishing on cloth lapping wheel with gamma alumina. (Right) Polished in conventional way, with the diamond polishing step being replaced by an intermediate wet lapping operation using a relatively coarse grade of alumina

grease base, a lapping lubricant is not needed; in fact, its use would cause excessive movement of the diamond particles during polishing. The paper laps are discarded as soon as they show signs of becoming "scratchy".

After polishing with diamond of No. 3 grade (or finer), the surface finish is adequate for certain kinds of metallographic examination and has the advantage of excellent flatness, with no rounding of edges and no relief polishing of hard constituents such as carbides. Good retention of nonmetallic inclusions and freedom from polishing pits are also realized. To obtain a completely scratch-free surface, the specimen is polished on a lapping wheel covered with a rayon nap cloth charged with a water suspension of gamma alumina having an approximate particle size of 1/10 micron and a pH of 9. Because of the preliminary preparation with the diamond abrasives, the need for intermediate wet lapping is eliminated, the time required on the final lapping wheel is only several minutes for most specimens and the advantages of the diamond polish are essentially retained in the finished specimen.

Inspection

Mixed lots of metal parts, distinguishable only by an analysis of their composition, are quickly identified with the aid of a portable comparator designed by the research laboratories of General Motors Corp., Detroit. The device also can detect chills in castings, and measure thicknesses of paint films and plated metals.

The instrument uses the principle of the thermocouple, except that instead of employing a loop of two dissimilar wires, the part being tested forms part of the loop. The two probe tips of the instrument perform the function of conventional hot and cold junctions at the points where they touch the metal under test, even though the two junctions are at equal temperatures because the part has a uniform temperature throughout. If the composition of the pieces tested is dissimilar, the dissimilarity will affect the thermo-emf. generated by the loop and this is recorded on the instrument's meter. Sensitivity is increased by suitable amplification of the extremely small voltages involved. The comparator can be adapted to different test problems by selecting probe tips which give the most sensitive needle deflections on the meter. Several sets are available in different alloys of steel and other metals.

The instrument has been used in problems involving mixed stocks. An example is S.A.E. 1112 and 1117 which would have been difficult to separate by routine methods (such as spark testing) because of the small difference of 5 points in carbon. It is equally well suited for separating finished components differing only slightly in chemical analysis, and for detecting chills in iron castings to avoid machining difficulties due to the resultant hard spots.

For measuring the thickness of plating and paint films, the reading on the test surface is compared with a similar layer of known thickness.

Fig. 2 – Hand Probe of the Thermo-Electric Metal Comparator Is Applied to Engine Valve, Giving a Voltage Reading on the Instrument Dial

A.I.S.I. Standard Boron Steel Compositions[a]

A.I.S.I. List Revised February, 1954

Openhearth and Electric Furnace Alloy Steels
(Bars, Billets, Blooms and Slabs)

A.I.S.I. Number *(b)*	C	Mn	Si	Ni	Cr	Mo
TS14B35 *(c)*	0.33-0.38	0.75-1.00	0.20-0.35	....	....	....
TS14B50	0.48-0.53	0.75-1.00	0.20-0.35	....	....	....
TS40B37	0.35-0.40	0.70-0.90	0.20-0.35	....	....	0.08-0.15
42B35	0.32-0.39	0.70-1.00	0.20-0.35	....	0.40-0.65	0.08-0.15
42B40	0.37-0.45	0.70-1.00	0.20-0.35	....	0.40-0.65	0.08-0.15
42B45	0.42-0.50	0.70-1.00	0.20-0.35	....	0.40-0.65	0.08-0.15
42B50	0.47-0.55	0.70-1.00	0.20-0.35	....	0.40-0.65	0.08-0.15
TS43BV12 *(d)*	0.08-0.13	0.75-1.00	0.20-0.40	1.65-2.00	0.40-0.60	0.20-0.30
TS43BV14 *(d)*	0.10-0.15	0.45-0.65	0.20-0.35	1.65-2.00	0.40-0.60	0.08-0.15
TS46B12	0.10-0.15	0.45-0.65	0.20-0.35	1.65-2.00	....	0.20-0.30
50B15	0.12-0.18	0.70-1.00	0.20-0.35	....	0.35-0.60	....
50B20	0.17-0.23	0.70-1.00	0.20-0.35	....	0.35-0.60	....
50B30	0.27-0.34	0.70-1.00	0.20-0.35	....	0.35-0.60	....
50B35	0.32-0.39	0.70-1.00	0.20-0.35	....	0.35-0.60	....
50B40	0.37-0.45	0.70-1.00	0.20-0.35	....	0.35-0.60	....
50B44	0.42-0.50	0.70-1.00	0.20-0.35	....	0.35-0.60	....
TS50B46	0.43-0.50	0.75-1.00	0.20-0.35	....	0.20-0.35	....
TS50B50	0.48-0.53	0.75-1.00	0.20-0.35	....	0.40-0.60	....
TS50B60	0.55-0.65	0.75-1.00	0.20-0.35	....	0.40-0.60	....
TS51B60	0.55-0.65	0.75-1.00	0.20-0.35	....	0.70-0.90	....
80B20	0.17-0.23	0.60-0.90	0.20-0.35	0.20-0.40	0.15-0.35	0.08-0.15
80B30	0.27-0.34	0.55-0.80	0.20-0.35	0.20-0.40	0.15-0.35	0.08-0.15
80B35	0.32-0.39	0.65-0.95	0.20-0.35	0.20-0.40	0.15-0.35	0.08-0.15
TS80B37	0.35-0.40	0.75-1.00	0.20-0.35	0.20-0.40	0.20-0.35	0.08-0.15
TS80B40	0.38-0.43	0.75-1.00	0.20-0.35	0.20-0.40	0.20-0.35	0.08-0.15
TS80B45	0.43-0.48	0.75-1.00	0.20-0.35	0.20-0.40	0.20-0.35	0.08-0.15
80B50	0.47-0.55	0.70-1.00	0.20-0.35	0.20-0.40	0.25-0.50	0.08-0.15
80B55	0.50-0.60	0.70-1.00	0.23-0.35	0.20-0.40	0.30-0.55	0.08-0.15
80B60	0.55-0.65	0.70-1.00	0.20-0.35	0.20-0.40	0.30-0.55	0.08-0.15
81B35	0.32-0.39	0.70-1.00	0.20-0.35	0.20-0.40	0.30-0.55	0.08-0.15
TS81B40	0.38-0.43	0.75-1.00	0.20-0.35	0.20-0.40	0.35-0.55	0.08-0.15
TS81B45	0.43-0.48	0.75-1.00	0.20-0.35	0.20-0.40	0.35-0.55	0.08-0.15
81B50	0.47-0.55	0.75-1.05	0.20-0.35	0.20-0.40	0.35-0.60	0.08-0.15
86B45	0.43-0.48	0.75-1.00	0.20-0.35	0.40-0.70	0.40-0.60	0.15-0.25
TS94B15	0.13-0.18	0.75-1.00	0.20-0.35	0.30-0.60	0.30-0.50	0.08-0.15
TS94B17	0.15-0.20	0.75-1.00	0.20-0.35	0.30-0.60	0.30-0.50	0.08-0.15
TS94B20	0.17-0.22	0.75-1.00	0.20-0.35	0.30-0.60	0.30-0.50	0.08-0.15
TS94B30	0.28-0.33	0.75-1.00	0.20-0.35	0.30-0.60	0.30-0.50	0.08-0.15
TS94B40	0.38-0.43	0.75-1.00	0.20-0.35	0.30-0.60	0.30-0.50	0.08-0.15
			BORON H-STEELS			
TS14B35-H	0.32-0.38	0.65-1.10	0.20-0.35	....	....	....
TS14B50-H	0.47-0.54	0.65-1.10	0.20-0.35	....	....	....
TS40B37-H	0.34-0.41	0.60-1.00	0.20-0.35	....	....	0.08-0.15
TS46B12-H	0.09-0.15	0.35-0.75	0.20-0.35	1.55-2.00	....	0.20-0.30
TS50B46-H	0.43-0.50	0.65-1.10	0.20-0.35	....	0.13-0.43	....
TS50B60-H	0.55-0.65	0.65-1.10	0.20-0.35	....	0.30-0.70	....
TS51B60-H	0.55-0.65	0.65-1.10	0.20-0.35	....	0.60-1.00	....
TS81B40-H	0.37-0.44	0.70-1.05	0.20-0.35	0.15-0.45	0.30-0.60	0.08-0.15
TS81B45-H	0.42-0.49	0.70-1.05	0.20-0.35	0.15-0.45	0.30-0.60	0.08-0.15
86B45-H	0.42-0.49	0.70-1.05	0.20-0.35	0.35-0.75	0.35-0.65	0.15-0.25
TS94B17-H	0.14-0.20	0.70-1.05	0.20-0.35	0.25-0.65	0.25-0.55	0.08-0.15

NOTE *(a)*—These steels can be expected to have 0.0005% min. boron.

NOTE *(b)*—All chemical ranges and limits are subject to the standard variations for check analysis over or under specification.

Phosphorus and sulphur limits for each steelmaking process are as follows: 0.025% max. basic electric furnace, 0.040% max. basic openhearth, 0.050% max. acid electric furnace and acid openhearth.

Maximum allowable quantities of unspecified and incidental elements are: 0.35% copper, 0.25% nickel, 0.20% chromium, 0.06% molybdenum.

NOTE *(c)*—TS denotes tentative standard steels.

NOTE *(d)*—These steels contain 0.03% min. vanadium.

Lift-truck fork weighs 150 lbs; a pair must support 4500 lbs 24 in. out from angle. Treating with AEROHEAT 1000 gives needed toughness and strength.

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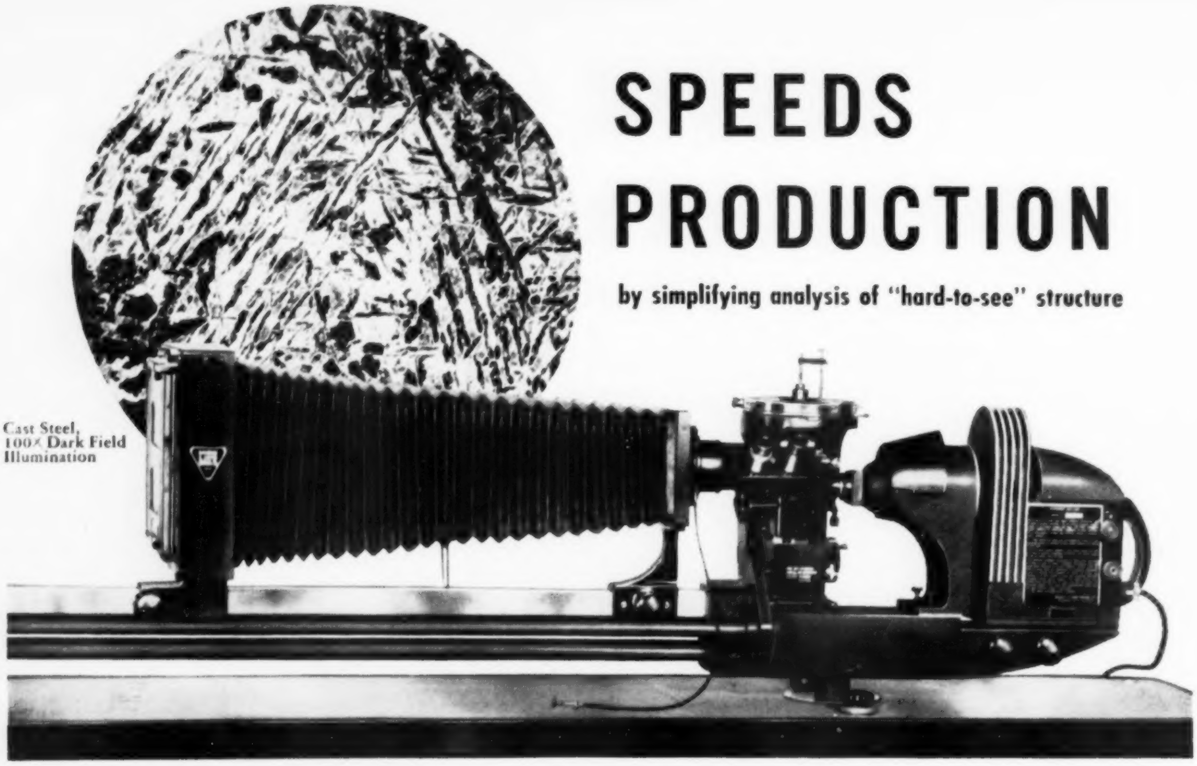


Cast Steel, 100× Dark Field Illumination

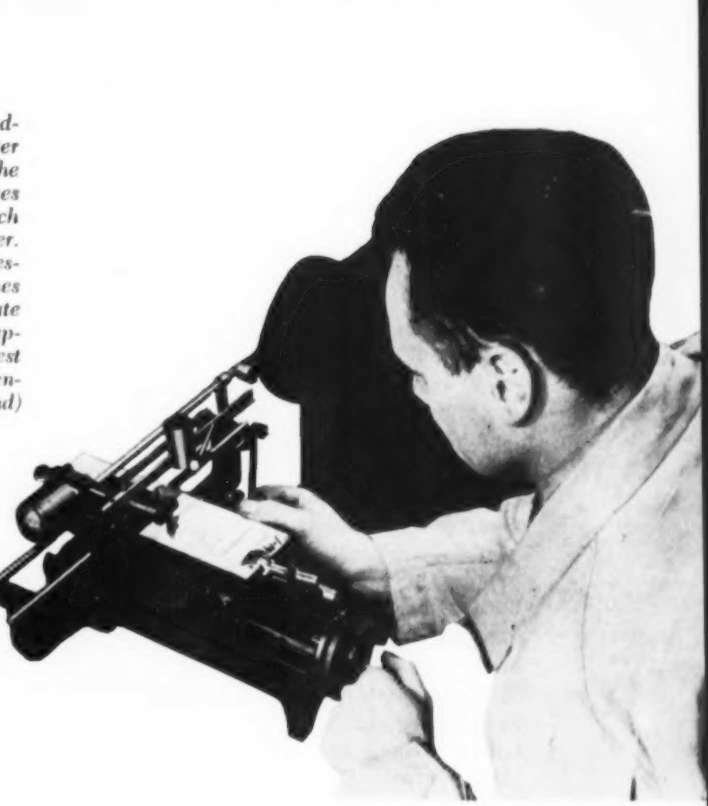


Fig. 1 – The Arco-Microknife for Measuring Adherence. A diamond point is weighted so that after two strokes across the panel in the same groove the paint film is just cut to bare metal. Parallel scratches are made as the panel is advanced, and each two successive scratches are closer together. Eventually the film tears between two successive scratches. The closer together two scratches can be brought without tearing the intermediate film, the better is the adherence rating. This apparatus makes quantitative a very old hand test practiced by paint men with a razor blade or penknife. (Photo Courtesy of the Arco Co., Cleveland)

Adherence of Paint Films

*By E. G. BOBALEK**

Paint formulation and the conditions for application of paint to metal surfaces are described in relation to the permanence of its attachment.

SOME paint films can be scratched or peeled away from a surface easily whereas others are difficult to dislodge. Such differences are not uncommon, even when supposedly the same paint is used over apparently identical surfaces. It is popularly said that one paint film has better *adhesion* than the other. Because the term is interpreted in different ways, it is perhaps a poor one to use; hence, it would be well to define this and other terms as they apply to this discussion.

Adhesion Versus Adherence—To most scientists, the former signifies the forces of either physical or chemi-sorption which attract and hold the paint film in intimate contact with the metal. Although measurement of these adhesion forces has been tried for many years, as yet no universally accepted methods have been found for defining or isolating it. In the limited sense of the above definition, adhesion is only

*Associate Professor of Chemistry, Case Institute of Technology, Cleveland.

one of the factors that influence the ease with which a film can be stripped from the metal. Brittle films, for example, are easy to scratch away even though their adhesion may be great, while rubbery or gummy films are more difficult to strip even though their adhesion may be no better, or even worse, than that of the brittle film. This composite of properties involving adhesion together with other physical characteristics of the body of the film determines the ease or difficulty of mechanically separating a paint from a surface. Therefore, it is this complex of properties and not adhesion alone that is evaluated subjectively when a paint is peeled with a fingernail or knife. A more quantitative and less subjective equivalent of the popular fingernail scratch test is to use a precision instrument like the Arco-Microknife (Fig. 1), or the Interchemical Adherometer (made by Gardner Laboratories, Bethesda, Md.). This practical quantity, which is easy to measure and which we call *adherence*, is the subject of this paper. However, adhesion is an important part of the adherence composite of properties. Consequently, it might be expected that such features as the chemical composition and structure of the metal surface which have significant effects on adhesion will also affect adherence. Recognition of this fact has influenced the growth of a complex science of preparing metal for painting. While the importance of metal preparation can hardly be overemphasized, nevertheless all adherence differences, and particularly substandard adherence, cannot always be blamed on improper surface preparation. More frequently than we realize, at least part of the trouble can be with the paint; more specifically, with the factors which affect the formation of films.

Assuming that the surface preparation of the metal is excellent and adherence differences are still apparent between supposedly duplicate samples of paint on metal—what, then, might be their explanation in terms of the vagaries of paint formulation and paint application?

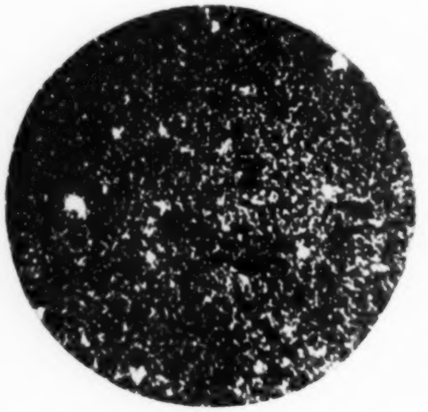


Fig. 2 – Although Clear Films of Lacquer May Apear Satisfactory in Ordinary Light, Dark-Field Illumination Will Show if Phase Separation Occurs With Incompatible Resins. (Courtesy of J. O. Small, Hercules Powder Co., Wilmington, Del.)

The Solvency Effect in Thinners – Most paints contain a pigment binder that is a mixture of two or more of the literally hundreds of synthetic resins available to paint formulators. Blends of various resinous binders, like nitrocellulose with alkyd, melamines with epoxy resins and many others, produce paints that are superior for specific applications, a condition which could not be obtained by using only one type of resin. The solubility characteristics vary with each resin type, so that only a limited number of solvents (or thinners) can be used to dissolve it into a liquid paint vehicle. When we mix resins of differing solubility characteristics, then also we must mix solvents so as to obtain a solution having the characteristics of a clear paint vehicle that is gel-free and of low viscosity. Manufacturing and selling costs compel the paint formulator to use the minimum practical amount of expensive true solvents together with the maximum permissible quantity of less expensive and effective solvents. The mixture of effective (true) solvents with the ineffective but tolerable (diluent) solvents is called the thinner. Only if this thinner is suited to a particular mixture of resins do we obtain a paint having stability when "packaged" and having satisfactory spraying, flow coating, dipping, and other application properties.

However, stability and ease of paint application are not the only problems in paint formulation. The different constituents of the thinner evaporate at different rates; hence, the proportions of the original solvent mixture are changing as evaporation of the thinner causes the paint film to solidify. Consequently, both the solvency and evaporation characteristics of the original solvent blend must be adjusted suitably so that the course of the evaporation process is such that the residual thinner still within the film will have adequate solvency to maintain in a single phase all the components of the resin mixture. Where this desirable situation prevails, the final solvent-free film will be a homogeneous resin mixture. If, however, the solvent balance is such that, as

evaporation progresses, one resin begins to precipitate ahead of the other, then the final film may not be a homogeneous or compatible resin mixture.

This is observed most frequently in nitrocellulose lacquer. For example, a solvent mixture may evaporate so as to preserve high solvency in its film residues when the film is air dried at 75° F. However, on a hot day, say 95° F., this favorable balance may be upset because the temperature coefficients of vapor pressure are not the same for all constituents of the thinner. At some stage during evaporation the residual solvent in the film can become too lean for some but not all components of the resin mixture. As a result, one resin of the mixture may precipitate ahead of the other resins. In clear films such separation causes unusual cloudiness of the film, and this effect is called a "resin blush". Severely blushed films generally have inferior physical properties and durability as compared to their clear standard. Fortunately, either when clear or pigmented, the lack of gloss and poor appearance are so evident that the need for stripping and repainting is obvious. In marginal cases, however, the effect of lower luster or cloudiness is not obvious by visual inspection in ordinary light. The difference can be seen, however, if one views compatible and incompatible clear films at an angle with a polarized beam of light or if films are examined by dark-field microscopy (Fig. 2).

Films in which marginal precipitation prevails differ in original physical properties such as flexibility and adhesion, or else their initially acceptable physical properties deteriorate more rapidly on aging. Whether the loss of properties is in adhesion or in other physical properties, such as elongation or fatigue resistance to cyclic thermal expansions and contractions, the result is almost always evident as a failure in the composite property of adherence. Marginal precipitation promotes film failure through "checking", "alligatoring", or "peeling" rather than through surface erosion, which is more characteristic of compatible and adherent films having the same composition.

Preparation of Thinners

Apart from the problem of solvency and resin compatibility, numerous problems can arise from disturbances resulting from vaporization of the thinner. When the evaporation rate is high, film turbulence can assume a steady state which will cause "orange-peel" texture or other irregularities in film thickness. Adhesion and other physical properties of films seem to vary with film thickness. If the film is not dimensionally homogeneous, the stress-strain pattern can be very complicated when such films are further distorted by mechanical or thermal stresses. Highly irregular films, particularly if the films are thin (0.6 mil or less), appear to be more brittle and less adherent than smooth films of the same composition. The poor adherence is worsened if the film bridges over air or vapor pockets within crevices of a rough metal surface. These effects are common when excessively volatile thinners are used, as in spray application of paint to minimize sagging of thick films of vinyl, chlorinated rubber, and other types of synthetic resin finishes. A subsequent baking operation will fuse and reflow the irregular film to give vastly improved adherence. If baking is not allowed, virtually the same improvements can be had using less volatile thinners and avoiding the effect of "dry spraying". The rate of evaporation of the thinner depends on the temperatures of the paint, the work coated, and the surrounding atmosphere and all these need to be held constant. A thinner suitable for one set of circumstances can result in appearance and adherence defects when conditions are changed.

Problems with solvents are not peculiar to air drying of lacquer finishes only. Most baking enamels contain mixtures of resins which must react with each other to form a hybrid resin if a homogeneous (compatible) film is to be obtained that will meet the required properties of appearance and durability. The course of these curing reactions within a paint film is affected considerably by the extent to which the mixed resins have or have not coagulated as a homogeneous gel during the period of evaporation of most of the thinner. Also, the quantities and solvency of the less volatile portion of the thinner retained in the film through a part of the baking period influence the curing reactions. Because solvents and thinners are formulated to fit particular conditions of paint application, apparently minor variables like prolonging "flash-off" time before baking or changes in the time and temperature schedules in baking ovens will drastically affect the results.

Serious faults caused by unbalanced curing reactions are visually evident as a degradation of luster. However, marginal defects which are not apparent to the eye nevertheless may have an effect in altering for the worse either the adhesion or mechanical properties of the film,

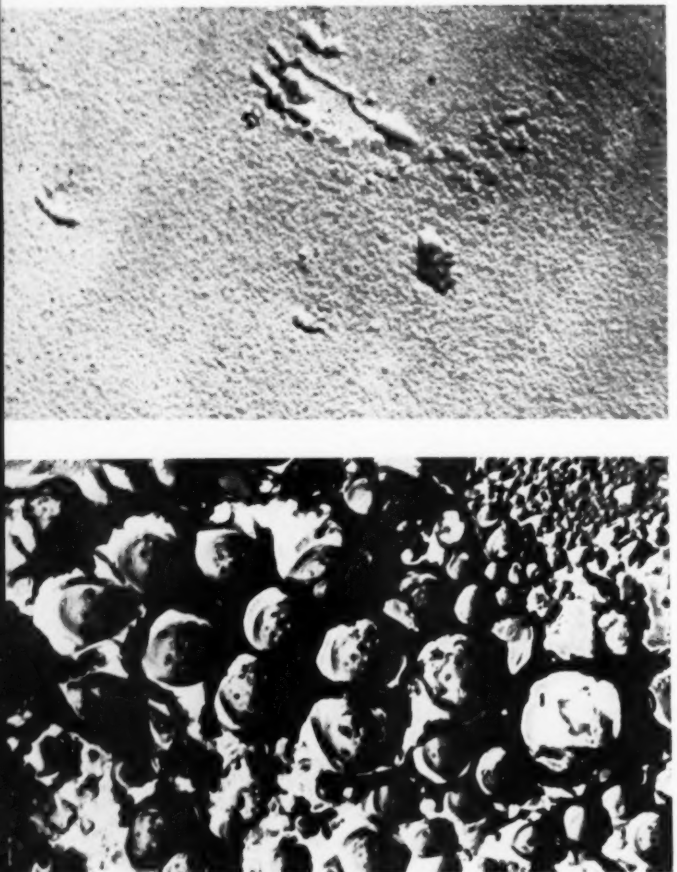


Fig. 3 – Electron Micrograph of Replicas of Two Surfaces of Epoxy-Resin Paints (Catalyzed to Cure at Room Temperature) of Identical Composition. The blistered film (lower) resulted when the paint was dried on a very humid day. The upper film showing ordinary structure was obtained on a later day when atmospheric humidity was low

or both. Such marginal defects become apparent later as more subtle differences in durability properties, such as resistance to salt spray and chemical reagents, and as underfilm corrosion in humid atmospheres.

Tampering with paint formulas in the finishing shop is a blind procedure, particularly when it involves substitution of one type of thinner for another. Every effort has to be made to keep the formula as specified. In general, paint application difficulties increase as the quality of the paint is improved in other directions, and there is less flexibility in altering the temperature conditions or schedules of paint application. If paint shop conditions cannot be controlled, it may be preferable to use paints of more mediocre quality with respect to appearance and durability, which, however, are less sensitive to formula variations or application conditions. Where precise control of painting conditions is possible, rigorous maintenance of these controls is necessary together with the exclusive use of formulas designed to fit these particular schedules.

Effects of High Humidity – The problems that metal foundries have in periods of high atmospheric humidity are a notorious fact. Few recognize, however, that problems in the paint shop can be equally serious. Conditions of high humidity can cause severe blushing of lacquers, which is detrimental to durability of physical properties of the film. Even for curing types of paints, high humidity alters the course of the chemical reactions and retards smooth evolution of volatiles so as to create disintegrating effects such as are illustrated in Fig. 3. Moisture condensation on the metal surface before painting, or the absorption of water into the wet paint film after painting, can impair wettability of the surface by the paint and cause "pinholing", or "crawing" of the film and a degradation of adhesion. These and other effects become the more serious as we strive to replace the old oil and varnish types of paints with more modern paints based on synthetic resins. At the present time the only remedy is to avoid use of the best paints unless temperature and humidity conditions can be controlled, or else to confine painting to periods of more favorable climate. Degradation of films caused by excess moisture may not always be apparent to the eye, especially for those superior anticorrosive finishes which normally have very little gloss, but the effect can be drastic in reducing resistance to blistering and peeling, and other durability properties which depend on good adherence and physical soundness of the film. Sometimes adherence stability may be adequate because the damage to the film is only superficial. However, failure by chalking can be accelerated in such superficially damaged films.

Wetting of the Surface

The spreading characteristics of a film determine the relative extent of penetration or bridging of the roughness pattern of a metal surface. This depends on the cleanliness of the surface and the intrinsic capacity of the paint liquid to wet the standard surface (see Fig. 4). The characteristic efficient wetting of the oxide layer of even clean metals is seldom an intrinsic

property of the resin or thinner constituents which make up the bulk of a paint composition. Consequently, this feature needs to be developed in the liquid either by unintended or deliberate contamination of the bulk material with small quantities of chemicals called surface-active agents. By a variety of mechanisms these additives promote a spreading of the paint film on a metal surface.

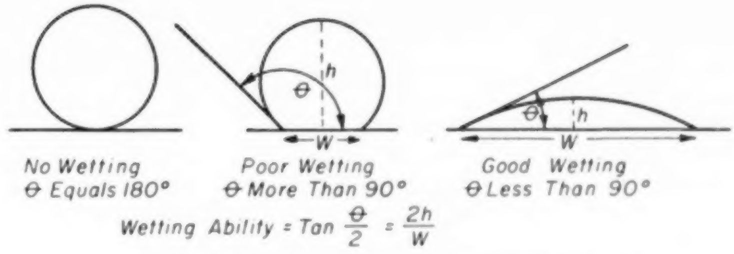


Fig. 4 – Schematic Illustration of "Wettability" of Paints in Terms of Contact Angle of a Drop of Liquid on a Metal Surface. Adding traces of surface-active agent can change the contact angle of paints, thereby affecting the ease with which a paint penetrates crevices and covers projections in a rough surface so as to form a fault-free and adhering film

The addition of specific flow-inducing substances to paint is an important part of the paint formulator's art – it is not to be practiced by the average paint user. In fact, trial-and-error experiments with the addition of surface-active reagents in finished paints are to be shunned. This warning is made to emphasize the fact that good or poor wetting of clean metal surfaces is a sensitive property that often depends on the presence or absence of trace quantities of specific chemicals in the paint. Reagents such as free vegetable oil, phosphoric or maleic acids are common additives. Trace quantities of beneficial agents can be destroyed by chemical reactions; for example, basic pigments might neutralize acidic surface-active agents, or the pigment may remove from solution by adsorption certain other types of soaps which are essential in promoting wetting. This change is slow; otherwise, it would have been detected in the ordinary course of testing of the paint. If, however, the paint has been stored overlong, then its wetting characteristics may decline and subsequent adherence of the dry film can suffer.

Prolonged storage may have other effects. For example, curing types of resins might gain in molecular weight and viscosity, which reduces the fluidity of the film and favors bridging rather than penetration of crevices in rough metal surfaces. Many problems of variable film properties in paint would not occur if careful inventory practice made sure that the paint first delivered was first out into the paint shop.

Cure and Film Shrinkage

Curing a resin may be represented as a process where short-chain molecules in the liquid paint vehicle become linked in complicated ways to give a fish-net or a three-dimensional cross-linked structure. If the film could be completely cured, all of the small resin molecules in the original paint vehicle would be tied into one large and complex molecule that retains the pigments and fillers. No paint film is actually cured so completely in practice. Ordinarily, the more the resin is cured the greater becomes its hardness and chemical resistance, and the greater is the loss in its flexibility. To achieve the optimum balance between chemical resistance and flexibility, extent of cure must be limited. The composition of paints is usually adjusted so that extent of cure will be optimum for particular specified baking conditions, catalyst concentrations, or other conditions of paint application.

An expedient tried frequently to increase the output of painted parts is to raise the baking temperature or add more catalyst. This may seem successful since a paint film is obtained which superficially resembles the old; however, the film may be overcured. Overcuring most resins past an optimum point causes severe shrinkage which pulls the film from its anchoring interface because cohesive shrinkage forces in overcured films exceed the strength of the metal-paint adhesion bond. Extreme manifestations of this fault are apparent as brittleness in the scratch test. Less severe overcuring also causes damaging "overcure" and can result in aggravating the tendency for films to fail by blistering, flaking, or checking during aging in service. The greater sensitivity to mechanical damage induced by overcuring does more harm than can be compensated for by even large improvements in the chemical resistance of the plastic itself. No matter how chemically resistant a paint film may be, it cannot protect unless

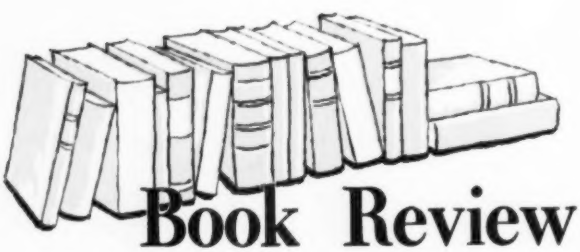
its adherence is sufficient and permanent.

If necessities arise which require accelerated paint drying, then it should not be done by haphazard variations of the old paint formulas which were designed for other conditions. Very probably there exists another formula, and possibly a cheaper one, which can be adjusted better to the accelerated application conditions which are desired.

Effect of Pigments

Some pigments, like a red lead and aluminum powder, can have a beneficial effect on adherence, either because their reaction products with the binder or metal substrate improve adhesion or because they inhibit the rate of deterioration of the flexibility of the film. Other pigments, like titanium dioxide, neither harm nor help. A few clays and some chromate pigments which contain too much soluble electrolyte may aggravate blistering tendencies and loss of adherence on exposure of the film to water or humid atmospheres. Some pigments, such as a few organic reds, may retard the cure of a film, while others like zinc oxide can accelerate the cure. Depending on what binder is used, these effects can be either harmful or beneficial.

There is hardly any plastic binder for paints which is not affected for better or worse by the pigments employed. Where the choice of colors is not prejudiced by other considerations, then any tests aimed at paint selection should search for not only an acceptable plastic base, but also the most favorable color to be used with that



Book Review . . .

Our Commonest Metal and Its Problems

*Reviewed by JOHN M. PARKS**

THE STRUCTURE AND PROPERTIES OF MILD STEEL by Prof. C. A. Edwards, University College, Swansea. 154 p. American Society for Metals, 7301 Euclid Ave., Cleveland 3, Ohio, 1953. $4.00.

WITHOUT question mild steel is the common metal of modern civilization; so common that it is frequently passed over by the modern metallurgist who is often feverishly chasing the complex properties of hardenable steel, super metal and wonder alloy. It is, therefore, quite appropriate that Prof. Edwards has taken the time to summarize his long and active study of mild steel and bring the whole subject to our attention in this age of accelerated metallurgical research, development and application.

All metallurgists will find his work stimulating as well as informative; documented not only with choice discoveries of the last decade, but those of the last two generations, and held together with the logical analysis and philosophy of a scholar devoted to his subject. Fortunately, the beginner as well as the master can learn by reading it – few will be left in doubt what is meant or implied; no complex mathematics blind the reader and confuse the issue. Yet, most of the problems and unknowns lay exposed for the

*Manager, Metallurgical Process Division, Air Reduction Co., Research Laboratory, Murray Hill, N.J.

plastic. Where choice of color is restricted, then all paint evaluations should be made in that standard color. Some resinous paint vehicles that may have been proved superior in the particular color in which they were tested, may be inferior to others in the untested color which the paint user intends to adopt.

Control of Secondary Factors

It would seem as if this article has wandered considerably from the theme of adherence in order to discuss the widest variety of film faults. This is the intent of the author. Adherence is a composite property involving adhesion and all other factors pertaining to the quality of the paint film. Most of the time, relatively little can be done to improve adhesion as compared to the ease and profit of making the other improvements that affect the permanence of attachment of a paint film to the surface we intend to protect. A large part, if not most, of the variations we observe in practical measurements of adherence are caused by these secondary factors which affect the body of the paint film rather than the adhesion interface. A brief account of these fundamentals of film formation as they relate to adherence has been attempted in this article. Years of trial-and-error experiments have demonstrated that relatively little control of interfacial adhesion is possible through the art of the paint formulator. Control of the *adhesion* part of the *adherence* variable is largely the province of science of metal treatment – a subject far too extensive for this article.

student of today to pick up and carry out; the book does not mislead the reader by furnishing an answer or explanation to every phenomenon that has been observed.

Starting with steelmaking, one is quietly exposed to the physical metallurgy of solidification and gas formation, crystal growth, composition effects, properties, aging effects, cold working and annealing, and pickling. When one is finished, the realization that mild steel still has many problems has been established; glamour has been added to the commonest of metals. All this has been accomplished without resort to reams of statistical data and deep and complex evaluations which confuse and tire the reader. Care was exercised also to avoid unsubstantiated postulates of our research associates, and the annoying ravings of patent-happy inventors. In short, the book is worth the time required to read and ponder.

Among the high points is the discussion of rimmed steel; when and why the gas bubbles form where they do. Also, the discussion of carbon solubility in ferrite, and the effect of chromium and titanium on this solubility, as indexed by tensile properties. The present reviewer has spent some time in this corner of the ferrous metallurgical field and can recommend as a supplement to Prof. Edwards' treatment a study of the work of Dijkstra on carbon solubility in ferrite, available either in Phillips' *Research Reports*, Vol. 2, 1947, p. 357 or *Transactions* A.I.M.E., Vol. 185, 1949, p. 252. This work, which I believe indicates a maximum carbon solubility in pure alpha iron of 0.021% and shows the method of determining it, is a classic. Certainly, those interested in research would be intrigued by pursuing the same method for evaluating the influence of titanium and chromium on carbon solubility in alpha iron, and comparing the results of determinations on damping capacity with those indicated by the change in yield point, so ably discussed in Chapter 3.

The nature of crystal growth found in ferrite may well astound many of the modern students of the subject who as yet have failed to measure up to the observations so clearly portrayed by Professor Edwards. Those concerned with the cold forming of soft steel will appreciate the discussion of stretcher strains and the yield point phenomenon in mild steel. Students of age hardening, strain aging, and quench aging will find food for thought; they may find herein an inspiration to study the subject more thoroughly.

Cold rolling and recrystallization is presented but slighted, perhaps intentionally – certainly it is a controversial subject where more is assumed than known. However, what is covered is well done. On the other hand, pickling and corrosion are well introduced; explanation is stopped short of the chaos that inevitably follows a comprehensive review of the data.

Correspondence . . .

Inspection of Stainless Steel Spring Wire

TURIN, ITALY

We in the Fiat industries use springs made of hard drawn stainless steel wire in many places where considerable corrosion resistance is required, as in water pump seals in gas engine cooling systems. This steel (which we import) is nominally 18% chromium, 8% nickel. Depending on source and shipment we find the chemical limits to vary considerably, namely 0.08 to 0.20% carbon, 18 to 20% chromium, and 8 to 10% nickel.

Mechanical properties depend upon size of wire and variations in mill practice, producer to producer. Ultimate strength may be 160,000 to 350,000 psi., "elastic limit" 70,000 to 250,000 psi., and modulus of torsion from 10,000,000 to 11,200,000 psi. After coiling, shot-peening the surface will double the safe stress range—for example, 45,000 psi. for unpeened springs, to 90,000 for peened springs.

This alloy resists atmospheric corrosion almost completely, as well as potable water at atmospheric temperatures. Some failures have been noted in salt water, but resistance is excellent to many different solutions commonly occurring in the chemical industry, if it is not in contact with metals which induce galvanic action, such as copper alloys.

Despite this good record, we have had some annoying failures in engine springs. These gave evidence of being caused by stress-corrosion, although it was suspected that some cracks may have existed within the wire as received. Consequently, we sought a test for selecting properly drawn stainless wire which would exclude those likely to precipitate the high-chromium carbides at grain boundaries. It is not sufficient merely to measure the magnetic properties of the stainless wire as received, since all small stainless wire (due to transformation of austenite to ferrite during cold work) is slightly magnetic.

We have been using with satisfaction the following test program for some time:

Three pieces, A, B and C are cut from each end of the coil, and stress-relieved at 575 to 660° F. for 30 min. Piece A is pulled in a tensile machine to gage internal soundness. Piece B is given a torsional fatigue test – the number of 180° alternate torsions to fracture in a piece 50 diameters long. Piece C is given the Strauss test for 72 hr. as recommended in Metals Handbook, p. 392, prior to the torsional fatigue test.

If the endurance of Piece C is then within plus or minus 5% of Piece B, the wire is considered acceptable on the basis of resistance to stress corrosion.

ALBERTO OREFFICE
Consulting Engineer
Fiat Central Laboratories

Quality of Cast Iron

HARTFORD, CONN.

Concerning Dr. Kosting's interesting contribution "Cast Iron Gun Tubes" in *Metal Progress* for May 1954, the following statement by William Metcalf, a metallurgical engineer of considerable prominence at the turn of the century, is pertinent (taken from A.S.T.M. *Proceedings*, Vol. 4, 1904, p. 15 and 16):

"I took a great deal of pleasure this morning in listening to the discussion of specifications for cast iron. I was at the business of making castings for guns at one time, where the government requirements were very specific and rigid. One of the chief requirements was, after the iron had been tested and approved as sufficiently strong for tensile, torsional and transverse resistance, to take a cylinder of 1-in. bore, 1 in. thick and about 6 in. long, and find its resistance to water pressure by applying pressure until the water was forced through the walls. The water was squeezed out as if from a sponge, and I never

knew a cylinder of that size to burst. After that test the cylinder was filled with wax and pressed again and generally the wax would burst the cylinder; but I have seen a cylinder even with such a stress on it spin out the wax as long as the length of this room without bursting. Finally, we had to take a specimen of iron and load it. I will not say positively what the rule was, but I think about two thirds the breaking strength, and if the piece failed to stand about 500 applications of that load the iron was rejected as not being sufficiently elastic.

"In making guns, the requirement was a density of 7.26. If it was below 7.24 or above 7.28, the Government reserved the right to reject it absolutely. The minimum tensile strength was 30,000 psi. from samples taken out of the sinking head of the gun. I may simply illustrate the character of the work we did by saying that in making more than 3000 guns during the war, we didn't have one gun rejected for failure to stand the tests, nor one for failure in the proving, and only a single report of a gun that failed during the war in service, and that report proved to be incorrect.

"In the 20-in. gun the casting weighed over 80 tons in the rough. The finished gun weighed 116,000 lb. The density of the sample of the sinking head was 7.26, the tensile strength 36,000 (plus) psi. We had to cast a square piece on the lower end for a hold in the lathe; when that was cut off, from curiosity we drilled a specimen out of it and tested it and it gave us a density, I think, of 7.27, and a tenacity of 42,500 psi., showing an increase of 6,000 psi., due to a head of about 25 ft. in the casting.

"In 30 years' experience after I left the foundry business I have rarely gotten a casting that will bear comparison to those we used to make, and I think you do need specifications to get your founders up to their work."

F. P. Gilligan
Secretary-Treasurer
Henry Souther Engineering Co.

Editor's Note—Some 50 years ago the "Metcalf test" was frequently used to judge the quality of toolsteel. It has now probably been forgotten, because several modern texts have no listing under "Metcalf" in their indexes. The test consisted of nicking all around a small bar—say ½ x 1 in.—at ½-in. intervals, heating one end only in a very hot forge fire until it was scintillating and the outer end not quite red, quenching in cold water, and breaking at each notch. File hardness, toughness and grain at each fracture were correlated for best hardening temperature (temperatures by color).

On "90% Martensite" and Answers to Inquiries

Editor's Note—In the steady flow of inquiries to the Society and *Metal Progress* on engineering and technical matters, a question is occasionally received for which we too would like to know the answer. When this happens we, in turn, call on friends for help. The following is an interchange of leters resulting from such request.

Coventry, England

I wonder whether you would be good enough to help me trace a technical query which, so far, has evaded my researches in this country.

In all the literature on application of hardenability to engineering practice, there are references to structures containing 50, 90 and 100% martensite, and I am particularly interested in the method of computing a 90% martensite structure.

I will be pleased if you would direct this letter to the correct source for information of available literature on this subject. I imagine it may be computed from hardness values at a certain position on hardenability curves, by microstructure, or by calculations based on a variety of assumptions.

H. H. Jackson
Consulting Engineer

Kearny, N.J.

Hodge and Orehoski (*Transactions* of the American Institute of Mining and Metallurgical Engineers, Vol. 167, 1946, p. 627) have shown that for a considerable number of low-alloy and medium-alloy steels, the hardness of the 90% martensite structure in quenched steel correlates reasonably well with carbon content in the range 0.15 to 0.8%. Thus, if high accuracy is not required, it is common practice to locate the 90% martensite structure from a hardness-versus-distance curve using the Hodge and Orehoski correlation.

Because the hardness of martensite may vary appreciably with cooling rate due to a "tempering" effect during slower cooling through the M_s-M_f temperature range and because the nature and hardness of the 10% aggregate structure also varies in hardness among different steels, more accurate determination of the 90% martensite location will ordinarily result from direct examination of microstructure. In comparatively high-alloy or high-carbon steels, which are likely to

contain considerable retained austenite, the 90% martensite structure should be determined from the microstructure.

The cooling rate for 90% martensite could conceivably be estimated from isothermal or cooling transformation data, but direct measurement is so easy there is little point in doing so. Where data are available for, say, a 99% martensite structure and a 50% martensite structure, the location of 90% martensite could be estimated by interpolation on a chart where percentage martensite is plotted on a probability scale against the logarithm of the cooling rate or against a scale of distance.

R. A. Grange
Research Laboratory
United States Steel Corp.

Metallurgy Needs a Huckster

Philadelphia

I have just read an editorial entitled "Trained Metallurgists Needed". After reporting on the shortage of metallurgists in industry, the article continues with: "Metallurgists are being made by practice rather than being trained by colleges – except insofar as a metallurgist is a converted mechanical or chemical engineer. Proof of this is the growth of the American Society for Metals – comprised as it is of men who have to know something about metals to hold their jobs or to grow into a better position. They have joined by the thousands to get this 'postgraduate' information."

Statistical data are quoted as to the low enrollment in metallurgy courses, and the article states: "The situation is even worse than it looks since too many of the metallurgical courses are given as options in mining schools and emphasize smelting and refining, sometimes to the total exclusion of the physical operations in the user's and fabricator's plants – a field where most of the new jobs will be found.

"What is really needed is ballyhoo; metallurgy has never been dramatized. War babies in metallurgy there were in plenty but they didn't get the publicity. For that reason, too many young men enter college with their imaginations kindled by the achievements of past days in other branches of engineering and without knowing the prospects of future success in the field of metals.

"The gist of the above has been said so many times it is almost bromidic."

The preceding statements are quoted from an editorial in *Metal Progress* for *December 1935!* In the last 19 years, apparently there has been little change in the relative situation. Except that the present war babies were in the period 1939-1945 instead of 1915-1918, the foregoing article is as applicable to the situation today as when it was written. However, the A.S.M. and the A.S.M. Foundation for Education and Research are now actively working to change this situation. May these efforts be successful!

R. M. Brick, Director
School of Metallurgical Engineering
University of Pennsylvania

Editor's Note – In his article "Metallurgical Education in the United States" *(Metal Progress*, March 1954) Professor Bornemann of Stevens Institute of Technology states: "Metallurgy is associated with mining both in the lay mind and in scholastic organizations." Apparently, nowhere near enough publicity has been given to metallurgy during the years between these two articles, by technical societies, by schools and universities, or by industry. It is realized as this is being written that the easiest of all pursuits is criticism – it calls for so very little effort. But a strong effort will have to be made to interest young men in obtaining a metallurgical education, and this will require from the technical societies, the schools and from industry intensive publicity campaigns that will describe not only past accomplishments of metallurgical engineers, but their increasing importance to industry and society.

Correction to Pahler Article; Barn Too Big

Monterey, Calif.

Since the Navy has been educating me in the field of nuclear engineering I found the article by R. E. Pahler "The Role of Beryllium in the Atomic Energy Program" (*Metal Progress* for April 1954) of considerable interest. I do believe that the printer played a trick on you and Mr. Pahler in the footnote at the bottom of page 87. As defined in that footnote, the barn is greater than the national debt of the United States (and there are very few quantities larger than that outside the realm of astronomy). Even though a wag is reputed to have first defined the barn by saying that it (the unit of nuclear cross-section) was as big as a barn, it is only large with respect to some other nuclear dimensions. No doubt Mr. Pahler intended that this unit should have been defined as 10^{-24} cm.

Robert S. Burpo, Jr.,
Lieutenant Commander, U. S. Navy

Personal Mention

Frank L. LaQue

Samuel J. Rosenberg

Frank L. LaQue ⊕ has been elected vice-president of the International Nickel Co., Inc., New York City, as well as manager of its development and research division. O. B. J. Fraser ⊕ and Donald J. Reese ⊕ will serve as assistant managers of the division. Mr. LaQue has been head of the corrosion engineering section of the division since 1945. A native of Gananoque, Ont., he received the degree of B.Sc. in chemical and metallurgical engineering from Queen's University, Kingston, Ont., in 1927, at which time he became associated with the development and research division of International Nickel, devoting his activities to the field of corrosion and corrosion resisting materials. He was assistant director of technical service on mill products from 1937 until 1940, and it was under his leadership that the well-known corrosion testing stations of the company at Kure Beach and Harbor Island, N. C., were established. A past president of the National Association of Corrosion Engineers, Mr. LaQue was recipient of the F. N. Speller Award in 1949. He is chairman of the advisory committee on corrosion of the American Society for Testing Materials and a member of the corrosion advisory committee, Prevention of Deterioration Center, National Research Council.

Samuel J. Rosenberg ⊕, of the National Bureau of Standards, has received the Department of Commerce Silver Medal for Meritorious Service. The award was made for "important contributions to the science and technology of physical metallurgy for over 30 years, including meritorious authorship". A native of Washington, D.C., Mr. Rosenberg received the degree of B. Sc. in mechanical engineering from George Washington University in 1924. From 1918 to 1920, he was employed by the Ordnance Office, U. S. War Department, and since 1920 has been on the staff of the metallurgical division of the National Bureau of Standards. He has made important contributions to the understanding of transformations occurring in ferrous materials and of the practical and theoretical aspects of the hardening of steels by heat treatment. Another contribution by Mr. Rosenberg has been in evaluating the rheological properties of both ferrous and nonferrous structural metals at subzero temperatures, and in establishing the limits of solubility of carbon in austenitic stainless steel. An active member of the Washington Chapter ⊕ for over 30 years, Mr. Rosenberg has served as chapter chairman, vice-chairman, secretary-treasurer, and chairman of the meetings committee.

Roy F. Hancock ⊕ has been appointed assistant vice-president of the Vanadium Corp. of America, New York City. Mr. Hancock, formerly assistant to the vice-president in charge of sales, has been affiliated with the steel industry since he was graduated in 1933 as a metallurgical engineer by Pennsylvania State University. He has been associated with Vanadium since 1950.

Edgar W. Engle ⊕, manager of product and process development engineering, Carboloy Dept. of General Electric Co., Detroit, has been named manager of cemented carbide products engineering. Mr. Engle has been active in manufacturing and developing cemented carbides since he went to Carboloy in June 1941 as a foreman. He became metal department foreman in 1945, manager of process engineering in 1950, and manager of product and process development engineering in 1952. He received a B. S. degree from Massachusetts Institute of Technology in 1941.

Vernon Swan ⊕, for the past few years ingot products supervisor at Reynolds Metals Co.'s sales headquarters, has been made manager of the firm's Plant 5 in Louisville, Ky. Mr. Swan, a graduate of the University of Wisconsin with a B. S. degree in chemical engineering, was employed from 1945 through 1950 by National Pressure Cooker Co., Eau Claire, Wis., as supervisor of both permanent-mold and die-casting operations, and prior to that time served as foundry metallurgist at the aluminum and magnesium sand foundries operated by Wright Aeronautical Corp., Lockland, Ohio. He joined Reynolds in 1950 as foundry consultant.

John W. Holzwarth ⊕ has been appointed manager of sales of heavy heating furnaces for the steel and nonferrous metals producing and fabricating industries and of all mechanical products for Salem-Brosius, Inc., Pittsburgh, with headquarters at the company's general offices in Salem, Ohio.

Wayne Rawlings ⊕ has accepted a position as metallurgist for the Stewart Warner Corp., Chicago.

(Continued on p. 128)

Personals

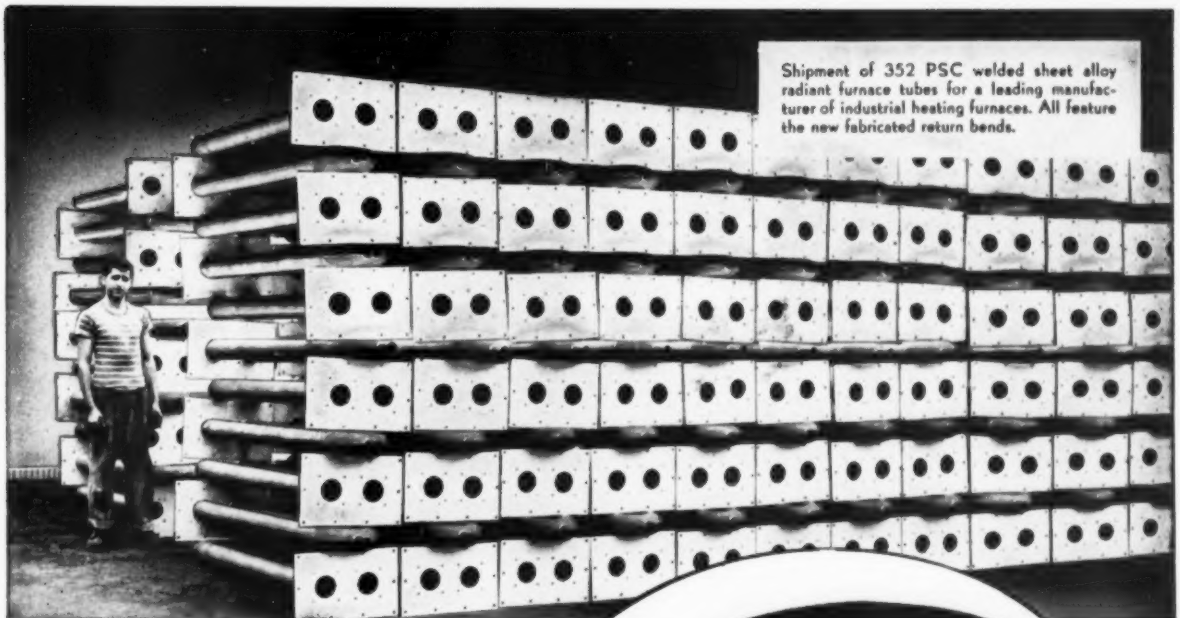
(Continued from p. 124)

Andrew N. Eshman has been appointed to the staff of the service engineering group of Mallory-Sharon Titanium Corp., Niles, Ohio, and will be responsible for engineering service to customers relative to fabrication, metallurgy and processing of the company's titanium sheet. A graduate in metallurgical engineering from Virginia Polytechnic Institute, Mr. Eshman has had varied experience as a metallurgist in the foundry and aircraft industries. After service as an Army Air Force pilot during World War II, he joined Buckeye Steel Castings, Columbus, Ohio, as metallurgist and assistant chief inspector. For three years he was a process and research engineer with North American Aviation Corp., Columbus, Ohio, where he served as chairman of the company's titanium committee and was responsible for the engineering phase of its titanium program. **L. M. Gary** has also been appointed to the service engineering group staff of Mallory-Sharon, and will be responsible for technical assistance to customers in the development and improvement of forging and fabricating techniques. Mr. Gary was formerly an independent consultant and advisor to the National Production Authority Light Metals Division.

John H. Zauner has been appointed chief engineer of Mills Industries, Inc., Chicago. Prior to this, Mr. Zauner was chief engineer of ordnance development and production programs at the Eureka Williams Corp., Bloomington, Ill. During World War II, he was senior engineer at the Applied Physics Laboratory of Johns Hopkins University and was responsible for development and production of all safety devices and arming mechanisms used in Navy proximity fuses.

David Rozet, who for the last three years has held the position of vice-president and director of research with the Weldwire Co., Inc., Philadelphia, has severed his employment with this company.

Robert A. Campbell is now employed as a metallurgist in the technical department of the Mueller Brass Co., Port Huron, Mich.



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of WILKES-BARRE, PENNSYLVANIA

Industrial Equipment of Heat and Corrosion Resistant WEIGHT-SAVING *Sheet Alloys*

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Personals

Roger Pinault, formerly development engineer with Quebec Iron & Titanium Corp., Sorel, Que., is now development engineer in the metallurgical group of Aluminum Co. of Canada in the Arvida, Que., works.

G. W. Reeder has accepted a position as metallurgical engineer with the American Welding & Mfg. Co., Warren, Ohio. Mr. Reeder was formerly manufacturing engineer in the metallurgical production division, Tapco Div., Thompson Products, Inc., Cleveland.

Lee John Droege, formerly plant metallurgist of the Schwein Engineering Co., Van Nuys, Calif., is now sales manager of the March Engineering Corp. in the same city.

C. James Dyer, Jr., who received degrees as B. Met. E. and M.S. from Ohio State University in June, reported to the U.S. Army on June 28 at Fort Knox, Ky., to begin a two-year tour of duty as second lieutenant.

James O. McCaldin, after receiving the degree of Ph.D. from California Institute of Technology, is with the research laboratories of General Motors Corp., Detroit.

Frank H. Smith has been elected president of the Smith Tube Corp., New York City.

R. H. Lambert, a captain in the U.S. Navy, has been transferred from shop superintendent at the Philadelphia Naval Shipyard to duty as inspector of naval material in Boston.

James A. Hereford has graduated from the University of Alabama with a B. S. degree in metallurgy, and is now employed by the National Tube Co., a division of U. S. Steel Corp., at Lorain, Ohio, on the student engineering program.

F. G. Hirschberg, general manager and chief engineer of Flinn & Dreffein Engineering Co., Chicago, celebrated his 25th anniversary with the firm on July 8. Mr. Hirschberg is widely accepted as an authority on conveyer-type furnaces.

Personals

Ernest S. Kopecki ⊕ has been appointed manager of public relations and promotion for Selas Corp. of America, Philadelphia. Mr. Kopecki received the degree of B. Sc. in chemical engineering at Marquette University and a master's degree in metallurgy at Carnegie Institute of Technology. Following separation from service with the U.S. Navy's Bureau of Ordnance, in 1945, as a lieutenant commander, Mr. Kopecki joined the staff of *The Iron Age*, where he subsequently assumed the position of metallurgical editor. He has been associated with the Carborundum Co., Niagara Falls, N.Y., for the past several years, where he served as assistant to the manager of public relations.

Ralph E. Alexander ⊕, major in the U.S. Marine Corps Reserve, is now technical sales engineer for the Los Angeles Plating Co.

T. L. Fritzlen ⊕ and **George Perkins** ⊕ were among the officials of Reynolds Metals Co., Louisville, Ky., who attended the Aluminum Centennial Congress held in the Sorbonne, Paris, France, June 14 to June 19. Dr. Perkins, director of products and applications for Reynolds Metals, read a paper on "The Technology of Aluminum Applications in the United States", and Mr. Fritzlen, the firm's chief metallurgist, had a paper on "Abnormal Grain Growth of Some Aluminum Alloys".

Edward B. Westall ⊕ has been promoted from plant manager of the California plant of the Borden Co. Chemical Div. to west coast regional general manager of the company with headquarters at Seattle, Wash.

Walter T. Bott ⊕ of the Moraine Products Div. of General Motors Corp. has been called into active duty with the U. S. Air Force and is stationed at Brooks Air Force Base, Texas, as a second lieutenant.

P. J. Atkas, Jr., ⊕, lieutenant, senior grade, in the U. S. Naval Reserve, has been promoted from chief physical tester and annealing and testing standards man to assistant rolling mill superintendent of the Seymour Mfg. Co., Seymour, Conn.

David B. MacFarland ⊕ has been transferred from sales representative in the Worcester, Mass., district of Universal-Cyclops Steel Corp. to warehouse manager in Titusville, Pa.

Robert C. Hammond ⊕ has been transferred from extrusion plant metallurgist at the Lafayette, Ind., works of Aluminum Co. of America to Alcoa's Vancouver, Wash., works, where in addition to the former position he is also metallographer.

Dilip K. Das ⊕, after receiving the degree of Ph.D. at the University of Notre Dame in June, has accepted a post as physical metallurgist with the Raytheon Mfg. Co. in the power tube division at Waltham, Mass.

Walter E. Littmann ⊕, of the metallurgical department, Steel and Tube Division, Timken Roller Bearing Co., Canton, Ohio, received the degree of D.Sc. from Massachusetts Institute of Technology in June. Dr. Littmann's research project was "The Influence of Grinding on the Structure of Hardened Steel".

(Continued on p. 132)

Personals

Norman A. Frank, formerly chief metallurgist with Aluminum Alloys Corp., Detroit, is now technical director and vice-president of Metallurgical X-Ray Laboratory, Inc., in the same city.

Bruce S. Crittenden has been promoted to sales engineer for the Dow Furnace Co., Detroit.

James Steele and **Richard Connell** have been appointed to new positions within the Sharon Steel Corp. sales organization. Mr. Steele, a sales representative in the Sharon district, has been transferred to the Philadelphia district sales office. Mr. Connell, who has been with the company since 1946 and in general sales office for the past several months, has been transferred to the company's Sharon district office as a sales representative.

H. Blumenthal has been appointed head of the newly created service department of the American Electro Metal Corp., Yonkers, N.Y. Dr. Blumenthal is also chief chemist for the company.

Fred R. Rowell has been appointed maritime representative for Robert W. Bartram Limited of Montreal, Que.

Joseph Henry LaRose, formerly with Wright Aeronautical Div. of Curtiss-Wright Corp. in Toledo, Ohio, has been elected president and director of Metallurgical X-Ray Laboratory, Inc., Detroit.

Herman Gardner has been transferred from the Wellington, Ohio, branch of the U.S. Plug & Fitting Co. to the Carrollton, Ohio, branch of the company, where he is general manager.

James D. Bean, who for the past five years has been employed by the John Deere Ottumwa (Iowa) Works in the department of metallurgy, has accepted a position as assistant development metallurgist for the Superior Tube Co., Norristown, Pa.

Carl L. Sonnenschein resigned as research and development engineer with New Castle Products, Inc., New Castle, Ind., to accept an assignment as project engineer with Mechanical Handling Systems, Inc., Detroit.

Delbert Dallefeld, formerly forging and casting production design engineer with McDonnel Aircraft Corp., St. Louis, is now employed as chief inspector of the forging division of W. Pat Crow Mfg. Co., Fort Worth, Tex.

Lee S. Garretson has joined the manufacturing engineering staff of the Dearborn General Mfg. Div., Ford Motor Co., Detroit, as a specialist in heat treat equipment and related problems.

Edwin O. Lomerson, Jr., is now employed as a metallurgist for the Pratt & Whitney Aircraft Co., East Hartford, Conn.

Edward S. Jones has been transferred from the General Electric Co.'s Research Laboratory in Schenectady, N.Y., to the G. E. Aircraft Gas Turbine Division, Cincinnati.

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Personals

Ryukiti Robert Hasiguti has been promoted from assistant to full professor at the University of Tokyo, Japan. Dr. Hasiguti is now professor of metal physics in the department of metallurgy.

T. K. Redden is now a technical sales engineer with the New York office of Titanium Metals Corp. of America, having transferred from the Henderson, Nev., plant.

Robert L. Burke, formerly production manager of Miller-Poston Mfg. Co., Spokane, Wash., is now production manager of the American Portable Irrigation Co., Riverdale, N.J.

John R. Kunkel is now employed in the general research laboratory of the Underwood Corp., Hartford, Conn.

Chester S. Shira has been transfered from the Atlanta, Ga., district office to the Jacksonville, Fla., branch office of the Lincoln Electric Co.

Joseph Finke has been transferred by the U.S. Atomic Energy Commission from its Savannah River, Ga., operations to the Reactor Development Div., Industrial and Production Reactors Branch, in Washington, D.C., where his position is assistant project engineer.

Thomas F. Conmy, Jr., after completing graduate work at the University of Notre Dame, has accepted a position as metallurgist with Corning Glass Works, Corning, N.Y.

Vaughn D. Hildebrandt has resigned as assistant professor of metallurgical engineering at the University of Illinois to accept a position in the research and development section of the magnesium department at Dow Chemical Co., Midland, Mich.

Alexander Squire has been appointed manager of the newly formed atomic power apparatus subdivision of Westinghouse Electric Corp., with headquarters at Large, Pa. In this capacity, he has the responsibility for the development, specification, and engineering procurement of apparatus for the nuclear power plants being built by Westinghouse.

Milton L. Godfrey is now associated with Talon, Inc., Meadville, Pa., as assistant manager in the production engineering division.

John E. Fogarty, formerly metallurgical project engineer in the Ballistics Research Laboratory of the Aberdeen Proving Ground, Md., has accepted the position of metallurgist in the research laboratory of the Republic Steel Corp., Canton, Ohio.

William F. Anderson, after three years as production engineer and more recently superintendent of production in the forge plant of Ford Motor Co.'s Aircraft Engine Div., Chicago, has accepted a position with Kropp Forge Co., located in the same city.

Charles R. Wirth has been named district representative by Eclipse Fuel Engineering Co., Rockford, Ill., for the company's newly established West Coast district office, the Industrial Combustion and Furnace Co., Glendale, Calif. Mr. Wirth formerly served Eclipse as a sales engineer in the Rockford area.

New Cu-Mn-Sn Alloys*

THIS REPORT describes a range of new alloys which may be useful in the fields hitherto served by nickel-silver. The alloys meet the demand for a "white metal" with good mechanical properties at a competitive cost, and one that can readily be cast, forged, rolled and stamped. It has an adequate resistance to corrosion and is satisfactory as a basis metal for the usual plating finishes used in industry. Of especial interest is the fact that the new copper-manganese-tin alloys may effect a useful economy in nickel, and field trials indicate that they may make a permanent addition to the copper-base alloys now employed.

Information is given about the properties of a wide range of compositions and how compositions and methods of treatment may be varied to alter properties such as strength, color and formability.

The development of alloys with substantial amounts of manganese is more attractive since electrolytic manganese became available, particularly if the manganese can substitute for a scarce element, such as nickel. Copper-base alloys with manganese and tin have interesting properties. Alloys with at least 15% Mn and at least 6% Sn are white. The resistance to corrosion of these alloys is believed to be adequate for many applications where nickel-silver is commonly specified.

A brief review of the binary phase diagrams may aid in understanding the ternary Cu-Mn-Sn system. The maximum solid solubility of tin in pure copper is 15.8% at 1110° F. If the body-centered cubic β is cooled to 1095° F., it decomposes into $\alpha + \gamma$. The γ phase decomposes eutectoidily at 970° F. into $\alpha + \delta$. Neither β nor γ can be fully retained by quenching. At elevated temperatures, manganese and copper form a continuous series of solid solutions. The solubility of manganese in copper decreases to little more than 20% at room temperature. The opinions of investigators differ concerning the binary diagram of the

(*Continued on p. 138*)

*Digest of "The Structure and Mechanical Properties of Copper-Manganese-Tin Alloys", by J. C. Blade and J. W. Cuthbertson, *Journal* of the Institute of Metals, Vol. 82, September 1953, p. 17-24.

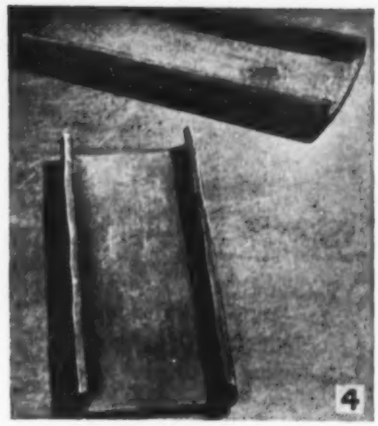
Syracuse cuts tray costs 96% with Inconel

...cuts tool spoilage, too

Breaks trays right and left . . . Nearly every working day, Syracuse Heat Treating Corporation had another silicon carbide tray (costing $3.25 each) broken while heat treating high speed tools. Often they lost four or five tools, as well. In one 5-month period the company replaced 90 broken trays.

Tries Inconel® . . . Because of Inconel's excellent record of withstanding heat and corrosion . . . because Inconel stays strong and tough when hot . . . because it doesn't break when dropped. Syracuse decided to spend $10.00 and try several Inconel trays.

Stops Thermal Shock Breakage . . . The company got immediate relief from breakage. Neither mechanical shock nor the thermal shock of clamping trays at 2300° F. with cold tongs fazed Inconel. Syracuse had no trouble with distortion either.



Cuts costs $282.50 . . . plus . . . In the first five months of using Inconel, Syracuse saved $282.50 (96%) in tray costs alone. Tool spoilage went down, too. The company considers that quite a return on its $10.00 investment for Inconel . . . points out (see picture above) that trays have lots more life left.

"The cost reduction through the use of Inconel . . . might appear to be fantastic," says Mr. Fred Hunter, General Manager of Syracuse Heat Treating Corporation, but it "is a matter of record."

It's a matter of record in many firms that Inconel saves money in high temperature equipment. And, it's easy to handle . . . readily shaped, welded, and machined.

So look into the hot spots in your plant. Maybe Inconel will save you money, too. To get more information, write for free booklet, "Keep Operating Costs Down . . . when temperatures go up."

THE INTERNATIONAL NICKEL COMPANY, INC.
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INCO NICKEL ALLOYS

Inconel *for long life at high temperatures*

New Alloys . . .

(Continued from p. 136)

tin-manganese system, but a number of intermetallic compounds are known to exist.

Manganese restricts the primary solubility of tin in copper. At 1110° F. the value drops from 15.8% with no manganese to 5.8% solubility with 20% manganese. Above the eutectoid temperature only one insoluble phase has been observed in ternary alloys in which the tin exceeded the primary solubility limit. This precipitate is feebly magnetic and is believed to be the β phase, Cu_2MnSn, previously reported by Carapella and Hultgren. At lower temperatures the β phase decomposes to γ and a hexagonal phase called δ'. The eutectoid transformation temperature varies from 970° F. with no manganese through 985° F. with 5% Mn, to a maximum of 1130° F. with 13% Mn, and then falls through 1110° F. with 15% Mn, to 1020° F. with 20%.

The character of the eutectoid may be varied by changing the rate of cooling through the transformation temperature, or by changing the aging temperature. Slow furnace cooling, or aging close to the eutectoid temperature, produces a coarse lamellar structure. Chill casting in a 10 x 2 x 1-in. iron mold produces an unresolvable sorbitic structure (presumably an unresolvable fine pearlitic structure). The amount of tin that can be retained in the γ solid solution decreases rapidly below the eutectoid temperature.

Aging at 930° F. the alloys that were previously quenched from 1200° F. causes a rapid precipitation of δ' both within the grains and at the grain boundaries. The amount of grain-boundary precipitate increases with the amount of tin present above the solubility limit. Alloys aged below 840° F. show a tendency to preferred precipitation at the grain boundaries and along crystallographic planes. Quenched and aged alloys that show continuous bands of δ' at the grain boundaries or along crystallographic planes are brittle. This brittleness can be reduced by cold working before aging.

After homogenizing at 1200° F. and quenching, ternary alloys with the following composition limits can be given up to 80% reduction by cold rolling:

Mn	Sn
5%	14%
10	12
15	10
20	8

Most of the gain in strength that accompanies cold rolling is obtained from reductions of about 50%.

Elongation of the homogenized alloys varied from 40 to 60%. The tensile strength of a wide variety of homogenized single-phase compositions varied only from 53,500 to 63,500 psi. Some increase in strength, coupled with a great loss in ductility, can be had by aging the homogenized alloys. Much more impressive gains, with strengths up to 115,000 psi., can be made by rolling the homogenized alloys to 50% reduction of area, but again most of the ductility is lost. If these hard rolled alloys are subsequently tempered or aged at 90 to 180° F. below the critical temperature, tensile strengths of 77,000 to 84,000 psi. and elongations of 10 to 20% can be obtained!

WEBSTER HODGE

Furnace Men Report on Advantages of Induction Stirrer*

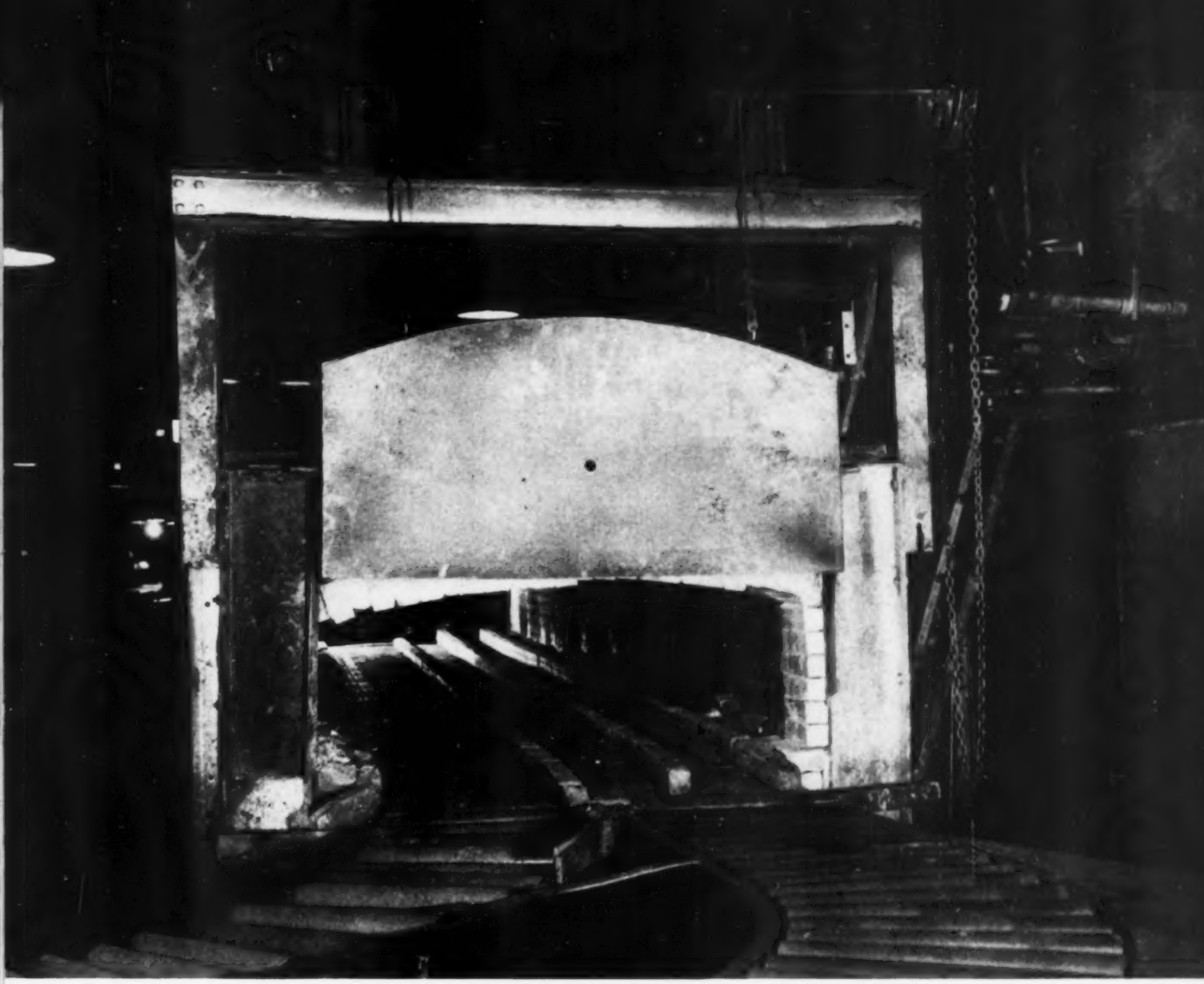
ONE OF THE most important recent developments in electric furnace steelmaking, the development and application of the induction stirrer, was described in papers by Harry F. Walther of Steel and Tubes Division, Timken Roller Bearing Co., Eric G. Malmlow of Aros Electric, Inc., and Quentin Graham of the Elliott Co. More than a year's use of this device on a 20-ft. arc furnace at the Canton, Ohio, plant of Timken Roller Bearing Co., has been critically studied by the operators; the advantages observed lead to the conclusion that the induction stirrer gives better control of the steelmaking process, is a practical tool, and can be used on any size arc furnace.

Induction stirring is a method of creating a stirring motion in the bath by applying electrodynamic force. The device may best be described as a section from the stator of a large polyphase motor. It combines a magnetic yoke with two coils connected to form a two-phase winding with two electrical poles. When mounted closely under the furnace, it forms with the metal bath what amounts to an induction motor, in which the moving magnetic field penetrates through the furnace bottom into the bath. When power is supplied to the coils by a two-phase alternating-current generator, a magnetic current is induced in the metal and consequently mechanical force, which causes the metal to flow along the bottom in the direction of the moving field, then up along the lining and back over itself. By reversing the current in one of the coils, the direction of travel of the magnetic field is reversed, and stirring is reversed.

The magnetic field diminishes with distance from the coils, and is further weakened as it penetrates the bath from underneath. The furnace bottom, corresponding to the air gap of the "motor", is 20 to 35 in. thick.

(Continued on p. 142)

*Digest of papers presented at the Electric Furnace Steel Conference of the American Institute of Mining and Metallurgical Engineers, Cincinnati, Ohio, December 2 to 4, 1953.



The three parts of this furnace that take the most abuse are all made of CARBORUNDUM's super refractories. The hearth and skid rails are silicon carbide. The piers are our electric furnace mullite—still going strong, after 5 years.

Not one repair in three years

Big, 300-lb. annealing baskets and 50-lb motor heads are pushed directly over the hearth of this furnace. Each type of work follows its own channel, formed by skid or curb rails. The wear-and-tear is constant and considerable—both on the hearth and the rails.

Originally, the hearth was made of fireclay, and the rails of cast alloy. But fuel and maintenance costs were so high that in 1949 a silicon carbide hearth was installed. This formed a hard, tough bearing surface for the work. It also transmitted the heat rapidly—and made possible *a saving of one third in fuel consumption.*

However, the Alloy Rails couldn't keep pace with the silicon carbide. They grew and twisted, and the furnace had to be shut down repeatedly for rail repairs or replacement. It was obvious that this was not "normal" maintenance because of the excellent condition of the silicon carbide.

So, on the recommendation of the plant engineer, the alloy rails were replaced with silicon carbide. This was early in 1951. And after three years on a two-shift operation, there have been *no rail replacements* due to wear!

HOW FREQUENTLY do your furnaces need attention? At today's labor and down-time cost-levels, *any* unnecessary shut-downs are too many. Change "normal" maintenance routines to long, trouble-free production runs with CARBORUNDUM's super refractories. Send for helpful literature.

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Induction Stirrer . .

(Continued from p. 140)

The bath can be considered a single conductor of the "rotor", and the decrease in flux therefore depends upon its depth. Since the weakening of the field also depends upon the frequency, the frequency must be very low to obtain suitable penetration into the bath, this being about $\frac{1}{2}$ cycle per sec. for a 20-ft. furnace. This gives a penetration of about $1\frac{1}{2}$ ft. and the speed of the traveling field is about 10 ft. per sec. at "high speed", resulting in a bath movement across the bottom of 3 to 4 ft. per sec. A "slow speed" gives a bath movement of 2 ft. per sec.

The induction stirrer is the invention of Dr. Ludwig Dreyfus of the Swedish Electric Co., ASEA. Originally developed in 1936, its first full-scale application was on a 15-ton arc furnace in 1939. This effort was unsuccessful but pointed out the need for certain mechanical modifications which permitted a successful application in 1947. Another unit was installed in 1948 on a 12-ton furnace, followed by four more in Sweden up to the present time. The results obtained were discussed in this country in 1949. The Timken Roller Bearing Co., after thorough investigation, then proceeded with the first installation in this country, which is the largest to date and was manufactured by the Elliott Co. Three more stirrers are soon to be installed in Europe, and one by another steel company in the United States.

It is considered likely that the same device, in principle, may be applied to other types of furnaces, as well as to metals other than steel. It can be adapted to curved or flat bottoms and requires only a limited space under the furnace. The important requirement is that the bottom of the furnace shell be made of nonmagnetic material having high electric resistivity to reduce eddy currents. Stainless steel proves quite satisfactory for this purpose.

The need for a suitable method of mixing the inactive bath in the arc furnace during later stages of the process was pointed out by Mr. Walther. Several methods have been used most of which were time-consuming and uneconomical, and which produced at best only a temporary effect. Continuous stirring, controllable both as to direction and velocity, avoids these objections. From experience to date, Mr. Walther cited the following advantages:

1. Thermal stratification is practically eliminated.
2. Bath samples for analysis are more reliable.
3. Solution of alloys is rapid and uniform.
4. With a slag equivalent to that normally used, sulphur content can be reduced quickly and to extremely low levels.
5. Slags are shaped up more quickly and controlled more easily.
6. Oxygen content of the bath is lower. This factor, combined with the motion of the metal, makes for more efficient use of deoxidizers.
7. As a result, grain size and cleanliness are better controlled.
8. More accurate temperature control generally leads to improved bloom surface.
9. Furnace time is saved at various stages. The motion promotes faster melting; oxidation and metal-to-slag transfer of impurities speed up; and slag-off is expedited by movement of the slag toward the furnace door.
10. Work on the furnace is easier in many respects, improving worker attitudes.

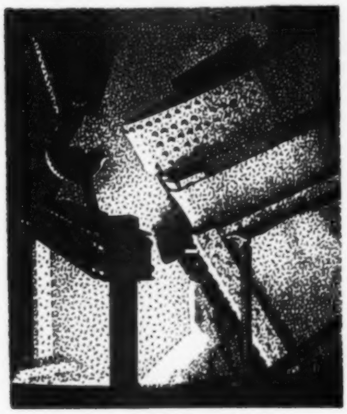
11. Erosion of the bottom is not appreciably greater than in non-stirred operation.

12. Maintenance costs are low.

This form of induction stirrer is not the only method of applying electrodynamic forces to stir the molten bath. There are several ways in which it might be done. At the present time, active development is in progress on a rotating type magnetic stirrer, which produces motion in the bath by moving magnets under the furnace bottom. This development was described by E. H. Browning and M. F. Jones of Westinghouse Electric Corp.

The relative values of the ASEA and rotary stirrers are not known. Interest is centered for the present upon the successful application of stirring in large arc furnaces, and mainly upon the ASEA unit because it is doing a good job in commercial use.

B. W. Farley



Alumina-Tipped Cutters*

Cutting tools, either single-point lathe tools or multiple-point milling cutters, tipped with sintered compacts of alpha aluminum oxide, have given excellent service on soft yet abrasive materials like plastics, composites, graphite, and certain aluminum alloys. The author outlines the methods used by his firm, B.S.A. Tools Ltd. of Birmingham, England, to manufacture these tips, tradenamed "B.S.A. Sintox".

The aluminum oxide normally

(Continued on next page)

*Digest of "Ceramic-Tipped Cutting Tools" by K. J. B. Wolfe, 5th International Mechanical Engineering Congress, 1953

Cutter Tips . . .

(Continued from preceding page)
contains small amounts of alkaline earth and alkaline metal oxides. Small quantities of chromic oxide (Cr_2O_3) are also added before fusion to help refine the grain of the solidified product. In fact, fine grain free of internal flaws or cavities is of the utmost importance to the raw material, and is achieved by techniques largely disclosed by A. L. Roberts in British Patent No. 626,445. In the sintering of compacts a little silica is used for flux; so far no suitable metallic binder has been discovered. Finally, those surfaces of the tip which attach to the shank or cutter-body are "metallized", so a firm joint can easily be made by brazing or silver soldering. Alumina tools are best ground with diamond wheels – 100-grit for coarse grinding, 200-600 grit for finishing.

The thermal conductivity (0.054 cgs. units) apparently gives a good balance – high enough so the shank draws off enough frictional energy to prevent overheating the tip beyond that point where a good deal of heat is put into the workpiece to "plasticize" the chip. Coefficient of friction against 8650 steel was determined by Messrs. Ernst and Merchant of Cincinnati Milling Machine Co. to be about 0.8 under normal operating conditions, as compared to about 0.9 for tungsten carbide – which the author, Mr. Wolfe, thinks may be due to the chemical inertness of alumina and no tendency to form a built-up edge. In single-tool lathe operation the finish is very noticeably smoother and more mirror-like with B.S.A. Sintox than when cutting with a carbide tool of identical size and conditions.

Some case histories are given. When milling a slot in clutch lining material the time for the alumina tool running at 2000 rpm. was 4 min; a high-speed tool running at 80 rpm. required 10 min. When turning highly purified components, the best performance of a high-C-V high speed steel was 5 pieces; carbide tools averaged 23 pieces; alumina tools 90. B.S.A. Sintox has also been able to machine ceramic insulator components (both unfired and fired) to better surfaces and with less tool wear than when carbide tools were used for this job. E.E.T.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strong
easy to
form
for everything
AND the kitchen
sink
SINK RIMS are an excellent example of Superior Stainless in service—all the way from initial ease of fabrication, through simplicity of installation, to life-long durability on the job. Rims of Superior Stainless stay bright with a wipe—can't rust, peel or chip—add value to the entire kitchen unit! ● Let's help you find your profit-application for Superior Stainless Strip Steel. Write us about your product, today.
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and here's why!

ALL-PURPOSE—Removes from metal parts practically every kind of foreign matter—waxes, oils, greases, gums, tars, chips.

QUICK ACTING—Cleans and dries rapidly. Low boiling range (86.6°-87.8°C, based on standard ASTM tests) permits vaporization at low steam pressure.

THOROUGH—Low viscosity (0.58 centipoises at 20°C) and low surface tension (about 29 dynes per cm at 30°C) assure diffusion into pores and relatively inaccessible openings.

SAFE—Has neither flash point nor fire point; classed as nonflammable at room temperatures, only moderately flammable at higher temperatures (Underwriters' Laboratories rating 3).

CUTS POWER CONSUMPTION—Can be heated by either gas, steam or electricity. Gives concentrated vapor at only 188°F. Specific heat less than ¼ that of water.

CUTS VAPOR LOSS—High vapor density (4.5 times that of air) assures proper vapor level at all times.

STABLE—Neutral stabilizer gives protection not only in the liquid but also in the vapor.

ECONOMICAL—Completely re-usable after distillation. And whether you buy by the drum or the carload, *you pay no extra premium.*

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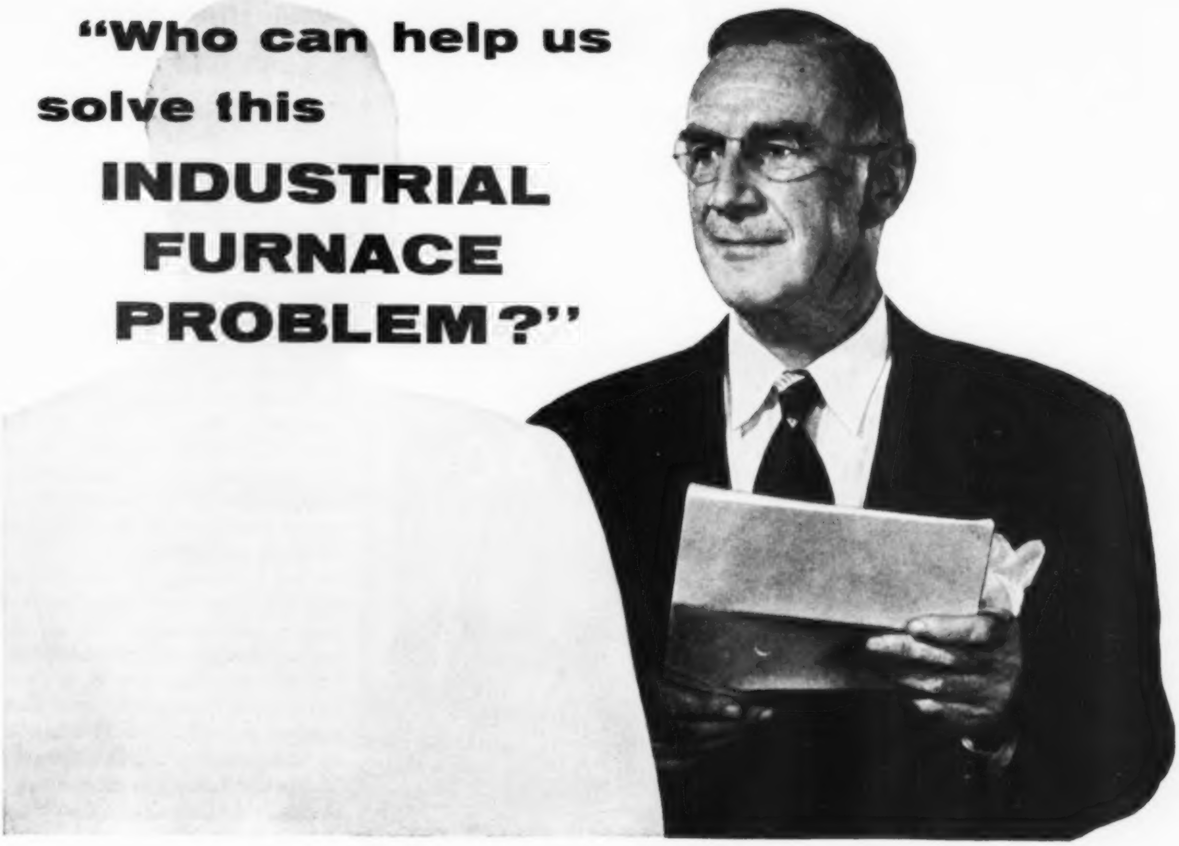
NIALK Caustic Soda · NIALK TRICHLORethylene · NIAGATHAL® (Tetrachloro Phthalic Anhydride)

"Who can help us solve this INDUSTRIAL FURNACE PROBLEM?"



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The engineers of the GLOBAR DIVISION of The Carborundum Company. For over 30 years now, they have worked with furnace users—and with over 40 manufacturers of industrial heating equipment—to find the right answers. If you have an industrial heating problem, or are planning to modernize any heat treating, sintering, brazing, annealing or forging operation, use GLOBAR's engineering service—without obligation.

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Comparison of Costs in Openhearth and Electric Furnace Shops*

In addition to the comparative operating cost and material balance in openhearth and electric steel furnaces, there are distinctive differences in performance and quality of the steel produced in each.

The operating features of an electric furnace differ greatly from those of an openhearth furnace with regard to flexibility and availability. An openhearth furnace, once started, must be kept in continuous operation for maximum economy. Whenever such a furnace is shut down, serious damage to the refractories always occurs, costly repair work is needed for starting up and also considerable time is necessary for both cooling and reheating. The electric furnace can be shut down and reheated with little loss of time or power consumption and with little damage to the furnace. This flexibility in starting and stopping the electric furnace makes it possible to operate the furnace on a full 24-hr. basis, or on a single or two-shift basis. In the event of decreased demand, the arc furnace may be operated fewer hours per day or at a lower melting capacity without much change in operating conditions or cost.

Since repair and maintenance on electric furnaces are less than on the openhearth, the availability of the arc furnace is estimated at 96% of operating time as compared to 92% as the best figure for the openhearth. This means that the latter is out of production, due to repairs, for about 30 days per year while the arc furnace only requires about 15 days per year. The replaceable roof of the arc furnace is the main feature in this respect since a spare roof may be kept available at all times and placed on the furnace in a few

*Conclusion of a three-part digest of "Comparative Economics of Openhearth and Electric Furnaces for Production of Low-Carbon Steel"; a report prepared by S. L. Case, D. D. Moore, C. E. Sims and R. J. Lund, Battelle Memorial Institute, of a study sponsored by the Electric Furnace Survey Group and Bituminous Coal Research, Inc. Published by Bituminous Coal Research, Inc., Pittsburgh; price $10. (The first two installments appeared in the June and July 1954 issues of *Metal Progress*.)

Cost Comparison . . .

(Continued from p. 146)

minutes. The small amount of refractory material in the electric furnace also greatly shortens a complete rebuild, since there are no auxiliaries such as ports, downcomers, slag pockets and checker work to be repaired.

The report also states that the ingot yield in the electric arc furnace is consistently 2 to 3% higher than in the openhearth furnace.

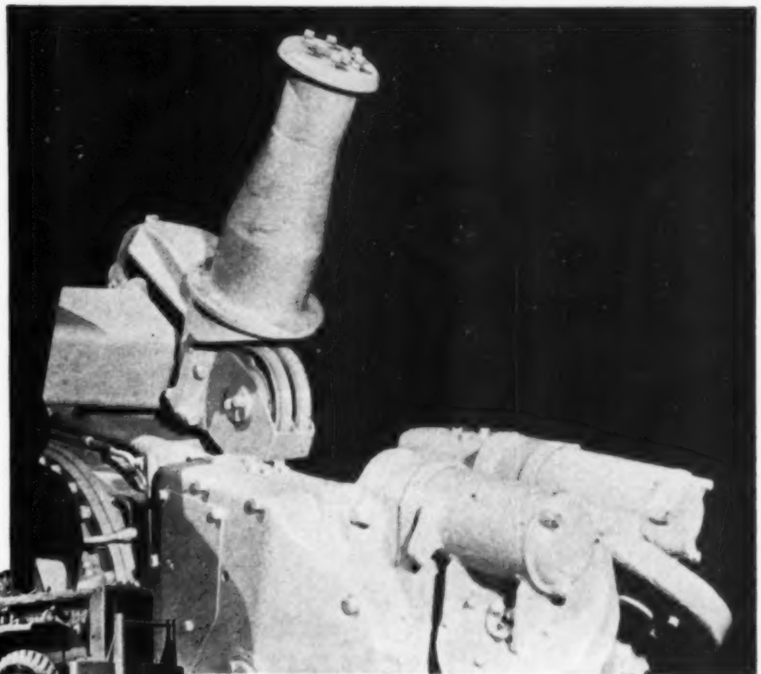
It is well known that an electric furnace steel of a given composition is generally more uniform and reliable than that produced in the openhearth. Since this report deals only with the production of low-carbon steel, the quality factor will be discussed on this basis. However, the electric furnace is adaptable to melting almost any analysis of any quality of steel and this flexibility is another important feature of the arc furnace. The large basic openhearth furnaces are definitely limited as to the analyses of steel which may be successfully melted. The fact that steel consumers have for many years paid an extra price for electric furnace steel of given analysis over openhearth steel establishes the real value of the quality factor.

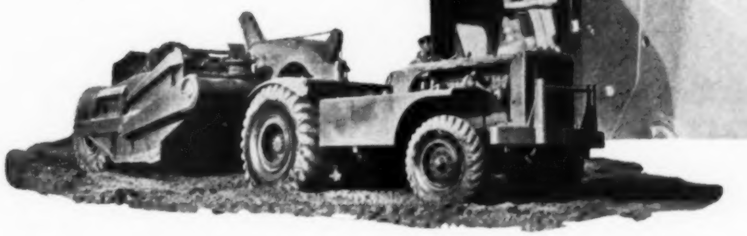
Difficulties caused by residual elements in the charge should be quite similar for both the openhearth and the electric furnace plants. The build-up of "tramp" elements in American steel plants has leveled off at about 0.014% tin, 0.11% copper, 0.08% nickel, 0.045% chromium, and 0.015% molybdenum. Since most electric furnaces have operated on a higher scrap charge than openhearth furnaces, the amount of "tramp" alloys in the electric steel might be higher than in an openhearth which has been charged with a smaller portion of cold scrap. In all other situations the contamination from tramp alloys would be similar if the same type of charge were used in either furnace.

It has long been known that the electric furnace is particularly adaptable for controlling the sulphur content of steel. Decreasing the sulphur content in the openhearth furnace is today a difficult and costly operation. The increasing importance of sulphur in deep drawing steel and

(Continued on p. 150)

Right: This "king bolt," made of Republic Alloy Steel, serves as hitch between tractor and trailer. Below: Caterpillar Diesel DW15 Tractor and No. 15 Scraper working on road job in Colorado.





How Republic Alloy Steels Help CATERPILLAR®

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Cost Comparison . . .

(Continued from p. 148)
welding operations increases the desirability of reducing the amount of sulphur in steel. At the present time there are numerous grades of steel for which a sulphur content of 0.025% max. is highly desirable. The openhearth furnace cannot produce such heats without great difficulty. The sulphur problem is becoming more critical each year with the use of high-sulphur coke in blast furnace smelting and the higher sulphur content in residual fuel oil. The sulphur content of the blast furnace has increased from 1 to 1.5% in the past decade, and the sulphur in fuel oil used in eastern parts has increased from 0.5% to approximately 1%. Both of these factors increase the sulphur content of openhearth steel.

In contrast, the electric furnace holds a favorable position. The use of electric power for heating eliminates the possibility of sulphur pick-up from fuel oil. Moreover, the sulphur content of the melt in the furnace may also be reduced by the use of specially prepared high-lime slags and it is possible to produce heats in the electric furnace (regardless of the raw materials charged) with a sulphur content below 0.03%. This facility of sulphur control may in the future become a very important factor in judging the relative merits of openhearth and electric steelmaking processes.

The authors also discuss the effect of the nitrogen content. It is well known that openhearth steel using a scrap charge low in nitrogen with a low nitrogen content in the hot metal can consistently produce heats containing less than 0.004% nitrogen. An electric furnace melt employing the same charge might pick up nitrogen from the action of the arc on the air in the furnace, and it has long been believed that the nitrogen content of electric furnace steel is higher than openhearth. The authors disagree with this assumption as it relates to low-carbon steels.

It is their opinion that low-carbon steel can be made in the electric furnace from a charge equivalent to that used in the openhearth with a nitrogen content that will not be any higher. This is based on the reasoning that the nitrogen pick-up in elec-

(Continued on p. 152)

Cost Comparison . . .

(Continued from p. 150)

tric furnace steel develops from three sources:

1. Fixation of nitrogen from the air by the arc.

2. Formation of stable nitrides by some of the alloying elements, particularly chromium.

3. Low rate of nitrogen elimination from the bath because of a very low rate of carbon removal, since the melt-down carbon content in production of alloy steels is only slightly above the final carbon and the slags are very reducing in the final stage of refining.

These conditions will not hold true in the production of plain carbon steels in a modern arc furnace for the following reasons:

1. In a modern top-charged arc furnace, air infiltration during melting may be kept at a minimum, so that nitrogen fixation by the arc should be relatively unimportant.

2. The absence of chromium and other alloying elements in the bath will prevent formation of stable nitrides.

3. The oxidizing slag which will be employed in production of plain carbon steel will facilitate an active carbon boil which, as shown by Sims, Moore, and Williams, will reduce the nitrogen content of the bath. The importance of producing an active boil must be recognized in future steelmaking in arc furnaces, particularly on grades adversely affected by nitrogen.

E. C. Wright

Selecting Metals for Oil-Film Bearings*

Score resistance, deformability, fatigue strength, corrosion resistance and cost are the five principal factors governing selection of metals to be used in plain oil-film or boundary-film bearings. Scoring of bearing metals should not be confused with cutting or grooving by dirt or other foreign material. It develops from metal-to-metal contact between journal and bearing

*Digest of "How Engineers Select Metals for Oil-Film Bearing Applications," by E. B. Etchells, *General Motors Engineering Journal*, Vol. 1, March-April 1954, p. 20.

The Schaible Story:

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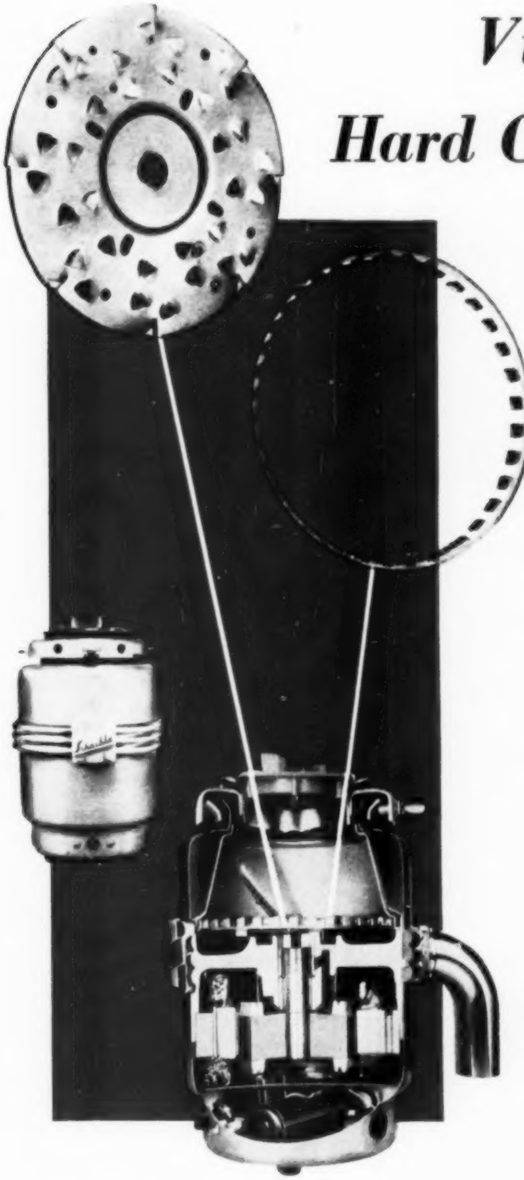

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Bearing Metals . . .

(Continued from p. 152)

due to starting, stopping, deflection and heavy loads.

White metals are used where score resistance or anti-seizure properties are a first requirement. They include the tin-base and lead-base alloys, commonly called babbitts, and cadmium. Following, in descending order of score resistance, are the copper-leads, aluminum alloys and leaded brasses and bronzes. Resistance to scoring can be improved in aluminum alloys, silver and copper, by indenting their surfaces with a fine grid pattern which then is filled with lead alloy, or by plating with tin or lead alloy.

Ability of a bearing to yield to deformation is important, as is its "embedability" characteristic. The latter pertains to dirt entering the clearance between shaft and bearing, either to embed in the bearing metal or to cut a groove around the contacting elements. Where dirt conditions are beyond control, white metals are preferred for bearings, despite their lower fatigue strength. When copper-lead, bronze or aluminum alloys are specified, the journals should be hardened to reduce wear.

Fatigue strength is a major factor with bearings under alternating or rotating loads, as in connecting rod and main bearings, and in piston pins of internal combustion engines. Failure starts as small cracks at the surface which progress to the bonding material and then travel parallel to the backing. When a large enough surface has fatigued, oil-film conditions deteriorate to produce failure by overheating.

Common bearing materials may be classified as to corrosion resistance as follows:

Noncorrodible – aluminum alloys, tin-base babbitt, lead-base babbitt (properly alloyed), cadmium-indium alloys, low-lead bronzes.

Intermediate – high-lead bronzes, copper-lead, alkali-hardened lead, silver (attacked by sulphur under certain conditions).

Corrodible – cadmium alloys.

It must be recognized that in the presence of certain lubricants, both the intermediate and corrodible materials may reverse their activity. In general, bearing corrosion has been


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Bearing Metals . . .

(Continued from p. 154)

lessened appreciably by the addition of detergents and inhibitors to lubricating oils.

Bearing metals may be rated in order of increasing cost in this way: bronze bushings, lead-base babbitt, tin-base babbitt, sintered copper-nickel filled with lead babbitt, solid aluminum alloys, cadmium alloys, copper-lead, copper-lead with thin overlay, aluminum alloys with thin overlay and silver with thin overlay.

Preferred structure of a bearing material is a soft matrix with sufficient plasticity to conform to slight irregularities in machining and alignment of the shaft and to allow any abrasive particles in the lubricant to become embedded. Balancing of mechanical properties requires resistance to shock of impact loads, accompanied by sufficient strength, ductility and resistance to compression, plus the ability to resist cracking or squeezing out under heavy loads at high temperatures.

Because of their ease of handling and low cost, babbitts are in wide usage. Either tin-base or lead-base alloys should have a minimum lining thickness effectively bonded to a steel backing, consistent with the conformability and embedability requirements of the application. Lead-base bearings have the advantage of lower cost but have less load-carrying capacity with low oil temperature, when thick linings are specified. With lining thickness less than about 0.005 in., little difference in load ratings is noted.

For higher loads, copper-lead bearings, backed by steel, are favored. They are made either by casting or by sintering of powdered metals. The two standard copper-lead alloys and their analyses are:

	S.A.E. 48	S.A.E. 480
Cu	67 to 74%	60 to 70%
Pb	25 to 32	30 to 40
Ag	1.5	——
Zn	0.1	——
P	0.025	——
Fe	0.35	0.35
Sn	—	0.05
Other	0.15	0.3

To gain strength, tin up to 3% and silver up to 5% are added at a sacrifice of anti-score qualities. This

(Continued on p. 158)

Bearing Metals . . .

(Continued from p. 156)

may be counterbalanced by overplating with a thin coating (0.001 in.) of lead alloy which results in one of the highest load-carrying plain bearings in use. They are frequently referred to as trimetal bearings.

Aluminum as a bearing material is not new, but until recently its application has been held back because of high coefficient of thermal expansion and poor bonding characteristics; now these deficiencies have been overcome. Three alloys in current use are:

	XB-805	750	GM-3889 M
Sn	6.5%	6.5%	0%
Ni	1.0	0.5	0
Cu	1.0	1.0	0
Si	0	2.5	4.0
Cd	0	0	1.0
Al	Bal.	Bal.	Bal.

The first is a strip alloy and includes a steel backing; the second is furnished without backing, while the third, developed by General Motors Research Laboratories, is produced by the strip process and is bonded to a steel backing by a relatively new method. The finished (trimetal) bearing carries a lead-tin-copper overlay not exceeding 0.001 in. thick. This electrodeposited surface has good ductility and scoring resistance, and contains sufficient tin to prevent corrosion, while the copper supplies strength and load-carrying capacity. Known as the Moraine-400, the bearing is classed in the moderate-cost, high-load, high-speed group, with an estimated six to ten times the life of conventional babbitt.

Two other bearing materials are in commercial use, although applications are limited. They are zinc castings and the porous type of sintered powdered metal. The former have low cost and will support low loads and operate at low speeds without scoring. The most common oilless or self-lubricating bearings are made by compacting 87.5 to 90.0% Cu, 9% Sn and about 1.5% graphite, all in powder form. Voids are controlled by particle size and compacting pressure so that when installed the bearings contain 15 to 35% impregnated oil. If correctly made they will function for life in specific applications.

Retention of Metal by Melting Flux*

An unusually interesting example of the application of painstaking testing, hand in hand with sound mathematical reasoning, is to be found in the method used by the authors in their study of the underlying causes of the retention of aluminum by alkali chloride fluxes during melting. Reference is made to the work of H. W. Gillet and G. M. James, reported in U. S. Bureau of Mines Bulletin, 1916, and to that of R. J. Anderson, described in "Secondary Aluminum" (Sherwood Press Inc., Cleveland, 1931). It is stated in this paper that "samples of flux were taken at various stages during melting of aluminum-silicon alloy scrap at about 1560° F. in an oil-fired rotary furnace. The appearance of the flux varied with the stage of the process at which the sample was taken. The flux was run out of the furnace and solidified in flat, shallow troughs. In this condition it was of a grayish-black color and when it was fractured trapped aluminum globules of various sizes could readily be seen."

Determination was made of the aluminum metal content as to total weight and size of particles. Microscopic examination showed needles of calcium fluoride in the early stages of melting. Later stages contained yellow-colored flat plates of alumina. It was noted that if the molten flux was stirred it seemed to become more fluid, agglomeration of the aluminum occurred, and the metal beads formed at the bottom of the crucible.

Qualitative experiments on synthetic fluxes and on the behavior of flux in contact with aluminum are explained, as are the results of these experiments which included fluxing and trapping of metal particles. Measurements of viscosity include an ingenious furnace arrangement to enable measurements to be taken at various shear gradients. The metal contained in treated flux was some 6% and the recovery about 3%.

H. J. Roast

*Digest of "An Investigation of Thickening and Metal Entrapment in a Light Alloy Melting Flux", by A. H. Sully, H. K. Hardy and T. J. Heal, *Journal* of the Institute of Metals, Vol. 82, October 1953, p. 49.


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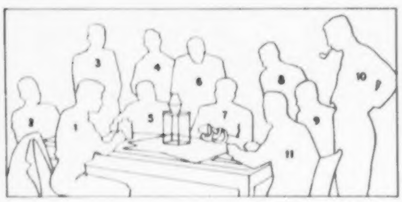

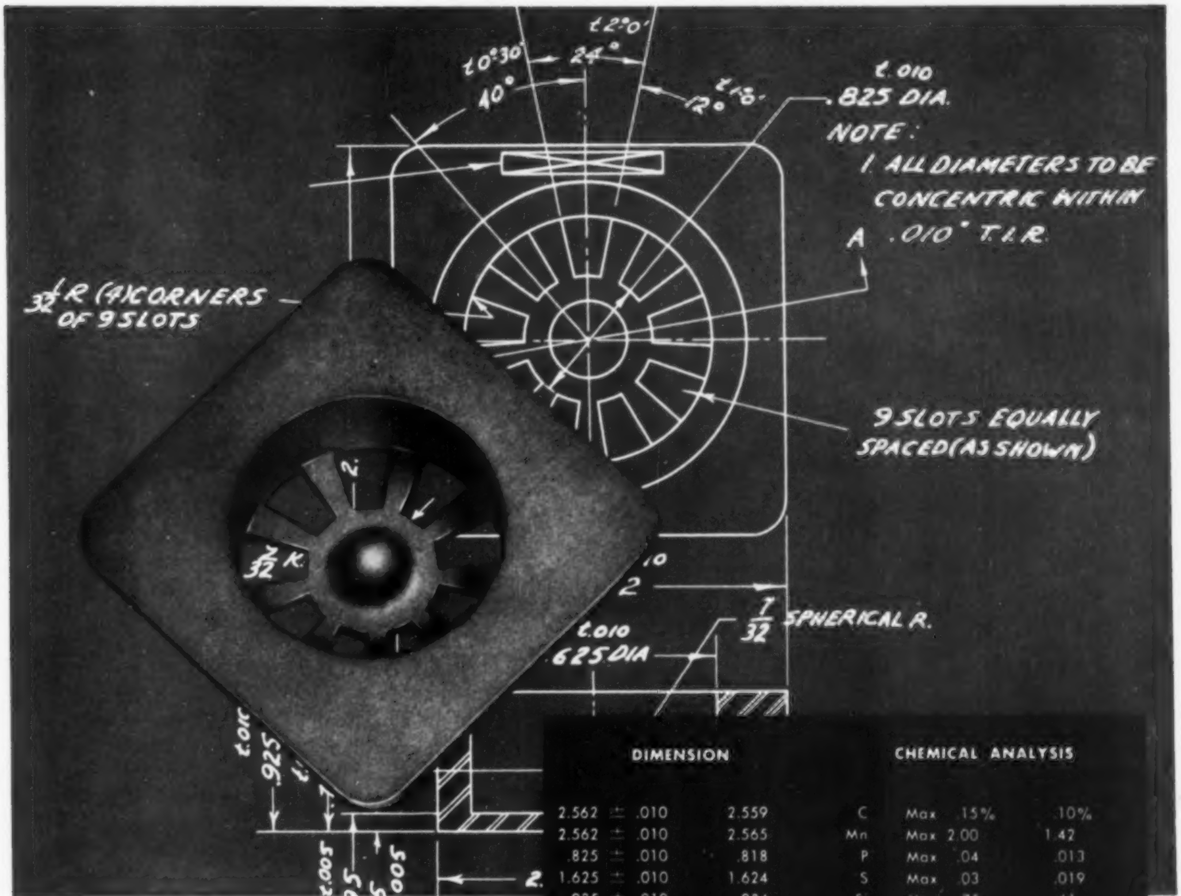

DIMENSION			CHEMICAL ANALYSIS		
2.562 ± .010	2.559		C	Max .15%	.10%
2.562 ± .010	2.565		Mn	Max 2.00	1.42
.825 ± .010	.818		P	Max .04	.013
1.625 ± .010	1.624		S	Max .03	.019
.925 ± .010	.924		Si	Max .75	.61
.700 ± .010	.698		Ni	12.00-14.00	13.00
.105 ± .005	.109		Cr	16.00-18.00	17.70
2.050 ± .010	2.058		Cu	Max .50	.07
.295 ± .005	.293		Mo	1.50-2.25	1.96

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Transformation During Welding*

INGENIOUS experiments were used to provide basic information needed to evaluate the recommended practice of preheating welds in steels for high-pressure steam lines between 400 and 600° F. and postheating at 1250 to 1350° F. These treatments are expensive and difficult to apply in practice. Besides, their metallurgical effect has been subject to considerable debate.

Two steels were investigated, one containing 1.25% Cr and 0.5% Mo, and the other 2.25% Cr and 1.0% Mo. Both contained about 0.10% C.

Upon ordinary heat treating, a body of steel is cooled from a uniform temperature, and the structural changes are determined by the various cooling cycles in the different parts of the block. In the heat-affected zone of a weld, each cooling cycle, in addition, begins at a different austenitizing temperature.

The authors determined the structural changes in a synthetic weld specimen consisting of two identical halves each 4 in. long, ¾ in. diameter over a 3-in. length and reduced at one end to a 4° tapered section 1 in. long and 0.187 in. diameter.

The two halves of this taper-bar specimen were fused together electrically over the reduced end planes. The dimensions of the taper-bar "are such that any specific location will experience essentially the same thermal cycle as a corresponding location in an actual weld heat-affected zone." (Obviously, dimensioning must be based on the geometry of the weld to be represented by the test bar.)

To produce a continuous cooling transformation diagram for a specific energy input, taper-bar specimens are quenched at various times after fusion and examined metallographically to determine the progress of transformation in the various zones. In principle, the method thus is the same as the one originally described in *Metal Progress* for January 1944, p. 94 to 99, the method being adapted to welding conditions by the substitution of a taper heated speci-

(Continued on p. 164)

*Digest of "Transformation of Cr-Mo Steels During Welding", by W. R. Apblett, Jr., R. P. Dunphy, and W. S. Pellini, *Welding Journal*, January 1954, Vol. 33, p. 57s to 64s.

Welding . . .

men for the uniformly heated Jominy test bars.

The CCT-diagrams with cooling curves and lines of beginning transformation developed for the two steels have been supplemented by the authors with simplified diagrams in which the ordinates represent the maximum heating temperature, and the abscissas the time of beginning transformations. This representation is made possible by the fact that a different cooling curve (associated with a definite time-to-start of transformation) begins at each maximum heating temperature. Since the maximum heating temperature in turn is determined by the distance from the line of fusion of the weld, the authors also have been able to show this distance opposite the maximum heating temperature on the ordinate axis, thus coordinating the maximum heating temperature (and time-to-start of a reaction) on the taper-bar with the appropriate distance from the line of fusion on the welded specimens.

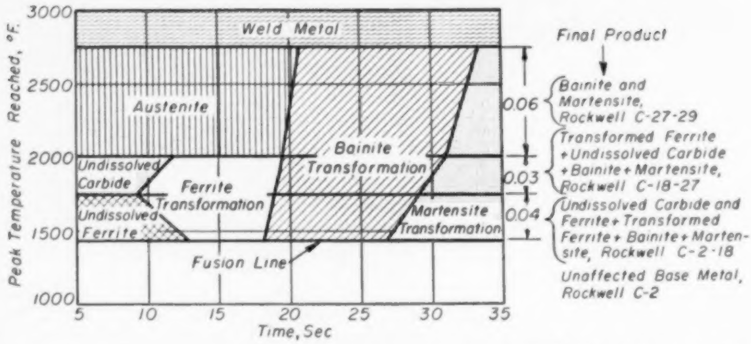


Fig. 1 – Simplified Version of Continuous Cooling Transformation Diagram for 1.25% Cr, 0.5% Mo Steel for Zone Affected by Weld Heat. The distances from the fusion line refer to the bead-on-plate weld

In supplementary welding experiments used to evaluate the practical inferences of the transformation data, the authors used an arc-travel speed of 6 in. per min. (0.1 in. per sec.); therefore, the distance in inches from a point under the electrode to a section where a transformation started equaled one-tenth the time-to-start of the reaction in seconds. Thus, a "simplified diagram" allows the site of a transformation during welding to be located with a ruler.

The steels underwent primarily a bainite reaction, and it was difficult to determine the end of transformations microscopically. Hardness determinations were considered to furnish the required supplementary information. For instance, the 1.25% Cr steel, having been heated between Ac_1 and 1800° F., experienced a hardness drop within 8.8 and 13.0 sec. and consequently was associated with rapid ferrite formation. A hardness drop resulting from

Welding . . .

(Continued from p. 164)

bainite reaction began after 20 to 25 sec. in sections heated to higher peak temperatures. After 31 sec. the hardness upon quenching closely approached the hardness resulting from cooling not interrupted by quenching, indicating the end of a bainite reaction after 31 sec.

The 1.25% Cr, 0.5% Mo steel transformed to ferrite when heated below 2000° F., but only to bainite when heated to higher temperatures. The bainite reaction started at about 1000° F. upon cooling from less than 2000°. However, when the heating temperature was raised, the reaction began at higher temperatures with the result that grain size increased and the austenite became more homogenous. The reaction continued to about 650° F., whereupon the austenite still remaining transformed to martensite upon further cooling.

Undissolved carbides existed between Ac_1 and 2000° F., so that the austenite originating in that region had lower hardenability. Between 1440 and 1750° F., austenite formed only in the regions surrounding the carbides. Just above Ac_1, the austenite formed a continuous network round the ferrite grains. This network transformed primarily to martensite, although some ferrite and bainite transformation also occurred.

The 2.25% Cr, 1.0% Mo steel formed less ferrite than the first steel. Upon being heated between 2000 and 2300° F., it transformed partly to delta ferrite which persisted on cooling and looked like enlarged carbides under the microscope.

To study the effect of preheat, the authors heated one end of an 18-in. long pipe specimen with a ring burner and cooled the other end with a water jacket. When temperature equilibrium had been established, a bead-on-plate weld was run down the length of the pipe using 180 amp., 25 v. and 6 in. per min. arc-travel speed, corresponding to an energy input of 45,000 joules per in. Uniformly preheated control specimens were found to give the same hardness distributions across the weld as the corresponding sections on the taper preheated welded pipe specimens.

Hardness traverses showed that

(Continued on p. 168)

Welding . . .

(Continued from p. 166)

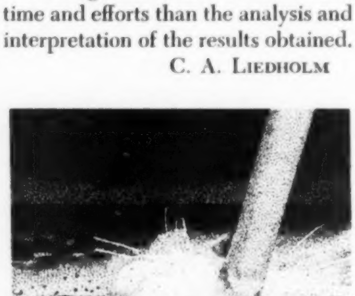
preheating at 600° F. reduced the maximum hardness by only 40 Vickers hardness numbers. The authors state that since bainite begins to form at 1000° F., as shown by the CCT-diagrams, preheating should be at least that high to induce complete transformation to ferrite and pearlite but that such preheating would not be practical. (It would have been interesting to know how much time these reactions would have required at that temperature. There are reasons to believe that this time would be very long.) Preheating at 600° F. "provides no beneficial metallurgical effects" but will often eliminate cracking of root passes under conditions of high restraint.

Reviewer's Comment

It is difficult to accept the thought that these ingenious experiments would have resulted only in the essentially negative conclusions reported by the authors. A description of the practical equipment and procedures used in welding pipe joints would have enabled an interested reader to speculate over the possibility of putting the findings to more productive use. For example, there are reasons to suspect that these steels might react quite rapidly in the pearlite range proper, so that a suitable postheating arrangement – trailing the welding electrode at a distance determined from the simplified diagrams – might have been used to induce complete transformation to ferrite and pearlite in a couple of minutes or so.

As often seems to happen in our contemporary industrial research, the planning, design and execution of the experiments appear to have received a greater share of the authors' time and efforts than the analysis and interpretation of the results obtained.

C. A. Liedholm



Sleeve-Bearing Alloys Susceptible to Cavitation Damage*

Erosion in the form of pits, occurring in ship propellers, in hydraulic equipment where high-velocity streams of fluid are encountered, and in sleeve bearings and gears operating in oil has become a familiar phenomenon. It is termed cavitation damage and is associated with discontinuities in the liquid stream or film in contact with the bearing metal. These points form a partial vacuum or a low-pressure area, with a bubble developing in the space which is filled with vapor, particularly when the pressure drops below the vapor pressure of the liquid.

If, under these conditions, high-frequency oscillating loads are applied, disintegration may result in the metal. Extent of damage depends upon many variables, including magnitude, frequency and duration of the force; the liquid; the surface, composition and physical properties of the metal; the mechanical design and operating temperatures.

In respect to sleeve bearings operating in lubricating oil, it becomes of interest to determine the extent and probability of cavitation damage. This can be done by means of an accelerated laboratory test.

The test apparatus is a high-frequency oscillator, operating on the principle that a metal rod or tube increases its length minutely when placed in a magnetic field, an action known as magnetostriction. Actual change in length is greater for nickel and its alloys than for other suitable materials, so a nickel tube is used to carry the test specimen. Displacement can be amplified considerably by employing the resonant frequency of the tube which varies principally with its length.

The electrical system includes a variable master oscillator, a driver amplifier and a power amplifier. The

(Continued on p. 172)

*Digest of "The Resistance of Some Cast and Plated Sleeve-Bearing Materials to Cavitation Erosion", by R. A. Schaefer, J. F. Cerness and H. A. Thomas, paper No. 26, Fourth International Conference on Electrodeposition and Metal Finishing, London, April 23, 1954 (*Transactions* of the Institute of Metal Finishing, 1954).

Corrosion can be controlled

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Because of its unusual design, this heat exchanger has two to eight times the heat-transfer of plain bare pipe or tubing. HASTELLOY alloy B gives the assembly the necessary corrosion resistance. The exchanger, which was formed from alloy B strip, pipe, and elbows, handles hot chloride-bearing chemicals.

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Cavitation Damage . . .

(Continued from p. 170)

master oscillator is set to generate a small voltage at 8000 cycles per sec. – the resonant frequency of the nickel tube and specimen. This voltage is stepped up by the driver amplifier which in turn furnishes the input power for the power amplifier. The latter supplies 500 w. to the driving coil which surrounds the nickel tube for about one-third of its length at the top and sets up an alternating magnetic field. A polarizing magnet is arranged to provide a magnetic bias for the nickel tube to allow it to vibrate as a half-wave oscillator.

Test specimens of bearing metals and alloys are applied to the outer face of a threaded plug machined from S.A.E. 1015 steel and screwed tightly to the lower end of the tube. A series of 23 commonly used bearing alloys has been studied, 17 of them cast onto the plugs, the others electroplated. Molten alloys were quenched with cold water at about 200° F. per sec., with the casting temperature 200° above the melting point. Plated materials were deposited on the steel base after cleaning, etching, and striking where necessary to insure adhesion. After deposition, the specimens were machined and polished.

The list of alloys included tin-base and lead-base babbitts, with and without antimony additions, Cu-Pb, Cu-Pb-Sn, Cd-Ni, Al-Sn-Cu-Ni, as well as samples of pure lead, silver, copper and tin.

All cavitation tests were performed with petroleum-base oil containing no additives and having a Saybolt viscosity of 123 to 128 at 100° F. and 33 to 34 at 300° F. The oil was treated by heating under a vacuum to remove air and water, then cooling, storing under a vacuum and using only once. Two runs were made on each bearing material, one at room temperature and one at 300 to 320° F., all of 30-min. duration.

To eliminate as many variables as possible, procedure was standardized. Oil height at the start of each test was approximately 1/32 in. over the face of the specimen, the latter, incidentally, being ⅜ in. diameter. Frequency of 8000 cycles per sec. and power input of 1200 w. were used throughout. Data were obtained by degreasing and weighing the specimens before and after each run. Weight losses were translated into terms of volume loss, since dimensional changes influence lubricant flow and mechanical loading in a far more significant way than do weight losses.

Results in general showed that most of the commonly used soft bearing materials suffer severe cavitation damage. Cobalt-plated 98-2 Ag-Pb and the cast 74-10-16 Cu-Sn-Pb alloys were considerably more resistant to erosion than all the other materials tested. However, these alloys are not ideal bearing materials, since they are somewhat hard and susceptible to seizure in high-speed operation.

Observation of the specimens always showed deep penetration or pitting once the surface had been punctured. Occasionally, the penetration was accompanied by distortion of the material around the pit to give a miniature crater effect. No specimens showed damage at the edges, probably because of the tendency for the gas bubbles to dissipate in the mass of oil.

In several cases of erosion, penetration reached the steel backing in the 30-min. test period, indicating that disintegration proceeded at a rate approaching 1 mil per min. and that the actual volume losses would have been greater if the thickness had been increased. It is considered likely that the characteristics of the backing material are important in determining the degree of erosion of thin layers, especially where pitting extends to the steel base.

Data pointed to no essential difference in the relative cavitation resistance of cast or plated alloys. Erosion was more severe at elevated temperatures for most alloys, exceptions being the plated and cast lead and lead-base alloys. Tin-base babbitts showed about twice the resistance at high temperature as the lead-base babbitts. A cadmium-nickel alloy, although a fairly soft material, had excellent resistance to cavitation damage.

Tests were run in spindle oil with no additives. Most commercial engine lubricating oils contain additives which may be specific to certain bearing materials. Thus their cavitation resistance may be modified from that determined in the laboratory research. A. H. ALLEN

Metals Engineering at

This Westinghouse 6000 C. F. H. Monogas® atmosphere generator is used in a variety of heat treating processes where an oxygen-free, non-decarburizing neutral atmosphere is required. Shown (l. to r.) inspecting the assembly prior to shipment are A. F. Snow, Design Engineer; C. E. Peck, Mgr., Industrial Heating Engineering and L. H. Gillette . . . all members of the American Society for Metals and readers of Metal Progress.

Pitting Corrosion of Copper Alloys*

THIS is a serious attempt to ascertain some of the fundamentals involved in the pitting corrosion of copper, and should be of informative value for those interested in the corrosion not only of copper but of copper-base alloys and others.

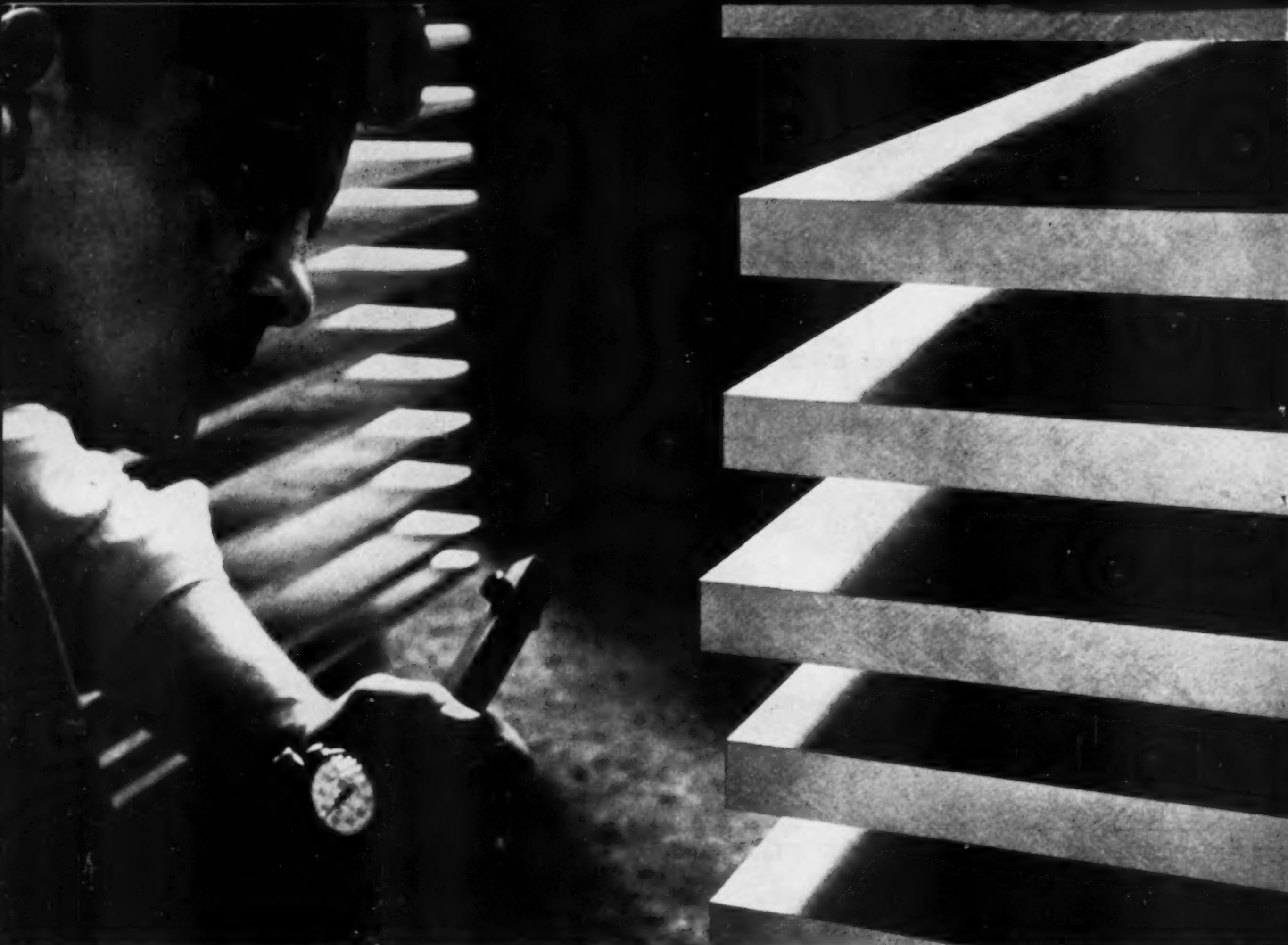
The clean copper surface is first attacked uniformly by the chlorides present, as for instance in sea water, basic salts being formed on the copper surface. Later a layer of cupric oxide replaces these salts, the layer thickens progressively, and since it is cathodic to the basis metal it will start pitting at any point where a local defect occurs. Points to be considered in the development of pits are the presence of porous crystalline cuprous chloride in varying amounts next to the metal at the anodic areas; the presence of varying amounts on top of the cuprous chloride inside the pit, or as a deposit at the entrance and often as a compact layer in direct contact with the metal at cathodic areas. The alteration in shape of pits gives an indication of changes in the local rates of anodic attack within the pit, and microscopic examination of the corrosion products gives useful information.

By using a water-immersion objective it is possible to watch the growth of cuprous chloride crystals. Various copper alloys, but not pure copper, may show a deep, narrow pit in which the attack is concentrated in the deepest part with little or no attack on the walls. In copper the pits become wider and deeper.

The influence of water movement is discussed and illustrations show how this is related to the nature of the attack. The latter part of the paper gives the conditions required for producing reproducible pits artificially. The design of a corrosion cell and its operation is fully described. It is believed that such a cell might form a valuable test for the rapid and direct demonstration of whether or not a given water could cause pitting corrosion.

H. J. ROAST

*Digest of "Some Observations on the Mechanism of Pitting Corrosion", by R. May, *Journal* of the Institute of Metals, Vol. 82, October 1953, p. 65-74.



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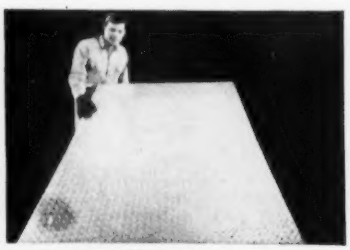

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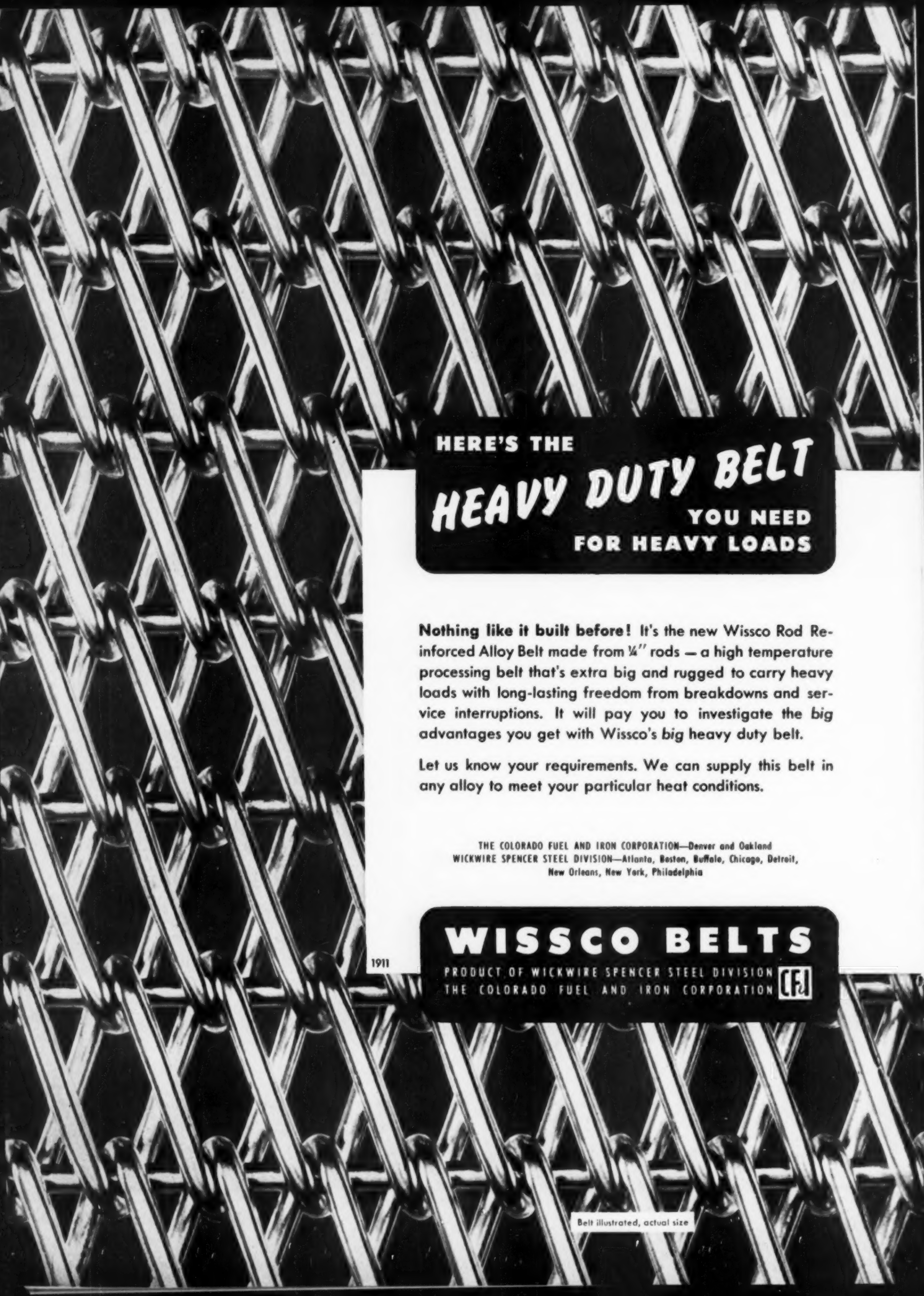
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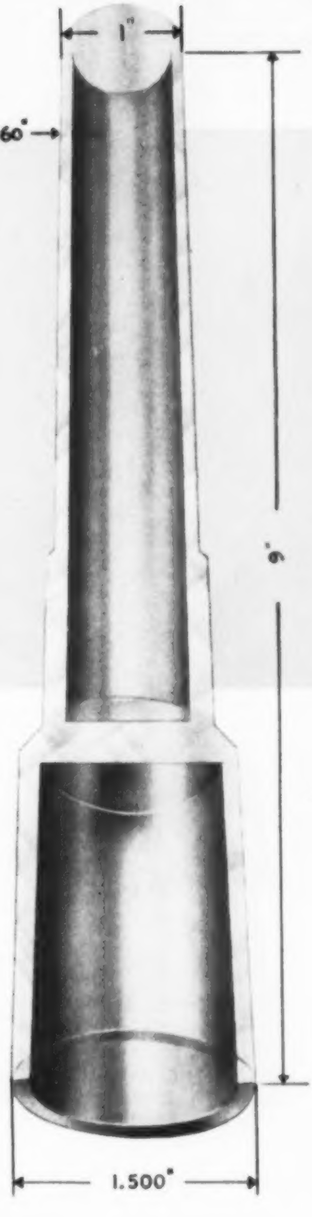

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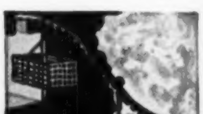

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Invitation to Entrants

9th Metallographic Exhibit

Entries are invited in the 9th Metallographic Exhibit, to be held at the National Metal Exposition in Chicago the week of Nov. 1 through 5, 1954. Entries will be displayed to good advantage and awards will be given for the best micrographs as decided by a committee of judges.

Classifications of Micros

1. Toolsteels and tool materials
2. Stainless steels and heat resisting alloys
3. Other steels and irons, cast or wrought
4. Aluminum, magnesium, beryllium, titanium and their alloys
5. Copper, nickel, zinc, lead and their alloys
6. Metals and alloys not otherwise classified
7. Series showing transitions or changes during processing
8. Welds and other joining methods
9. Surface phenomena
10. Results by unconventional techniques (other than electron micrographs)
11. Slags, inclusions, refractories, cermets

Awards and Other Information

A committee of judges will be appointed by the Metal Congress management which will award a First Prize (a medal and blue ribbon) to the best in each classification. Honorable Mentions will also be awarded (with appropriate medals) to other photographs which, in the opinion of the judges, closely approach the winner in excellence. A Grand Prize, in the form of an engrossed certificate and a money award of $100, will also be awarded the exhibitor whose work is adjudged best in the show, and his exhibit shall become the property of the American Society for Metals for preservation and display in the Society's National headquarters in Cleveland.

All photographs may be retained by the Society for one year and placed in a traveling exhibit to the various Chapters. They will be returned to the owners in May 1955 if so desired.

Rules for Entrants

Work which has appeared in previous metallographic exhibits held by the American Society for Metals is unacceptable. Photographic prints shall be mounted on stiff cardboard; maximum dimensions should be limited to 15 by 22 in. Heavy, solid frames are not permissible because of difficulties in mounting the exhibit. Entries should carry a label on the face of the mount giving:

Classification of entry
Material, etchant, magnification
Any special information as desired

The name, company affiliation and postal address of the exhibitor should be placed on the BACK of the mount.

Transparencies or other items to be viewed by transmitted light must be mounted on light-tight boxes wired for plugging into lighting circuit, and built so they can be fixed to the wall.

Entrants living outside the U.S.A. should send their micrographs by first-class letter mail endorsed "Photo for Exhibition—May be opened for customs inspection." To be acceptable as first-class mail the package should measure no more than 35 x 45 cm. (14 x 18 in.)

Exhibits must be delivered before Oct. 15, 1954, either by prepaid express, registered parcel post or first-class letter mail, addressed to:

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36th National Metal Congress and Exposition

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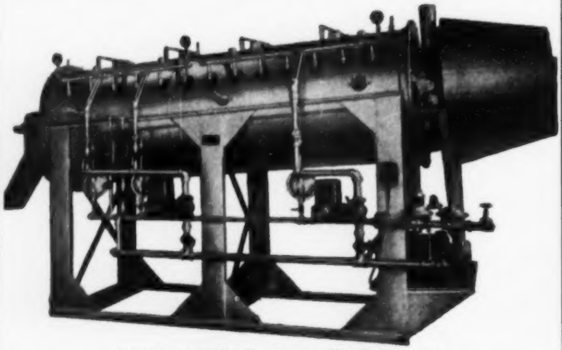

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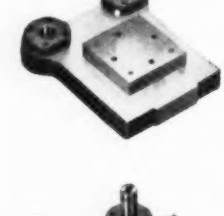

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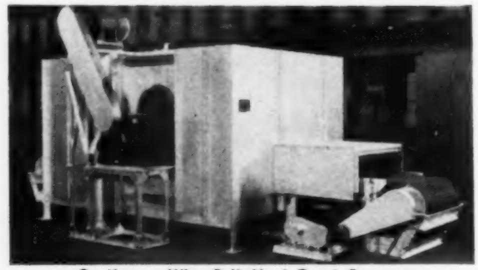

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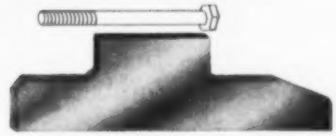
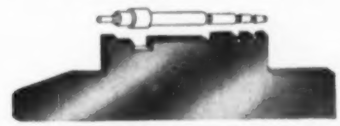


LEADING BOLT MAKER

PART	Hardened Alloy Steel Stripper Bolt.
OPERATION	Grind O.D. of bolt body.
MACHINE	No. 2 Cincinnati Centerless Grinder.
BLADE	Standard Talide-tipped Infeed work support blade No. 223877.
RESULTS	Talide-tipped blade gave 1600 hours of continuous service compared with normal production of 20 hours obtained with high-speed steel blade.



LARGE ELECTRIC MOTOR PLANT

PART	Stainless Steel Rotor Shaft for Electric Motor.
OPERATION	Grind 7 diameters simultaneously.
MACHINE	No. 2 Cincinnati Centerless Grinder.
BLADE	Special multiple step Talide-tipped work support blade No. C-4884.
RESULTS	Talide-tipped blade in continuous production for 91 days (2 turns per day) compared to best previous production run of 3 days with hard alloy steel blade.

LARGE MID-WEST BUSHING PRODUCER

PART	Cast Bronze Bushing.
OPERATION	Grind O.D. of bushing body.
MACHINE	No. 12 Landis Centerless Grinder.
BLADE	Standard Talide-tipped thru-feed work support Blade No. CA-32328.
RESULTS	Talide-tipped blade maintained size without scoring or scratching while grinding 1,000,000 hard bronze bushings—previous Stellite blade wore out after grinding only 40,000.

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Galvanizing Aluminizing Bright Annealing and Normalizing Strip ------ Continuously

Strip in single or multiple strands up to a total width of 54" may be bright annealed or normalized, continuously, in this EF gas fired radiant tube installation. Capacity 7200 lbs. per hour.

A large capacity continuous strip normalizing, annealing and galvanizing unit. This is a combination EF gas fired radiant tube and electrically heated installation and is over 400 feet long.

We are in position to design, build and put in operation: continuous strip lines for hot or cold rolled, high or low carbon, stainless, silicon, tinplate, aluminum, brass, bronze or any other ferrous or non-ferrous strip—for bright annealing, normalizing, galvanizing, aluminizing, tinning or any other process—in the size and type best suited to your plant, process, product or production requirements. No job is too large or too unusual.

Put your production furnace problems up to experienced engineers—*it pays.*

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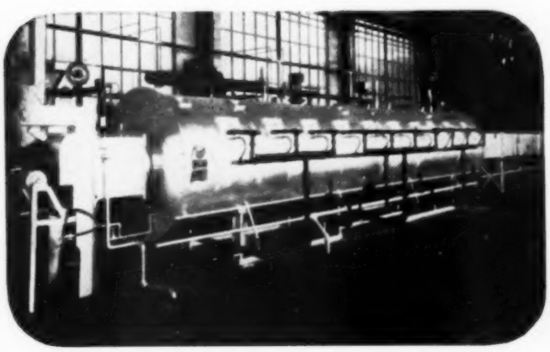
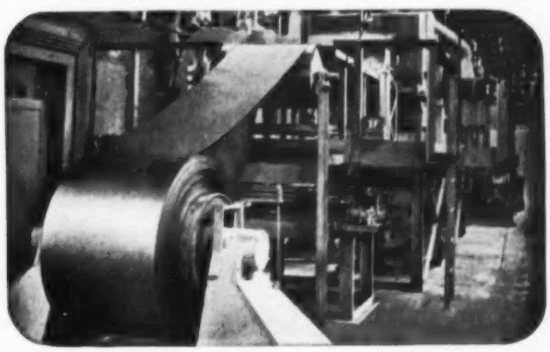


Stainless steel strip is bright or process annealed, continuously, in this EF gas fired special atmosphere tube muffle type furnace. It also handles other strip requiring lower temperatures.



An EF special atmosphere furnace with flame preheating burn-off or oxidizing section, and controlled heating and cooling zones for producing various surface conditions on strip.